

## Predicting range shifts of African apes under global change scenarios

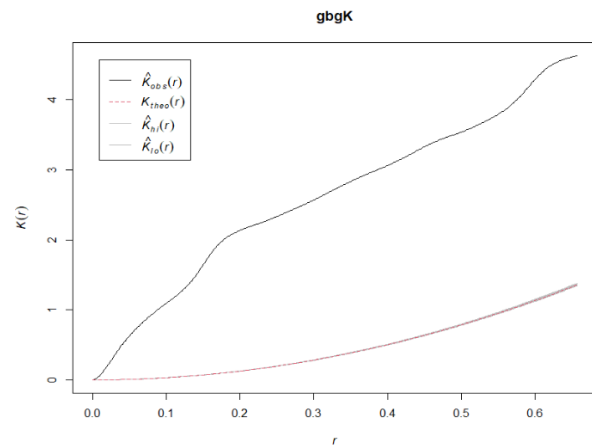
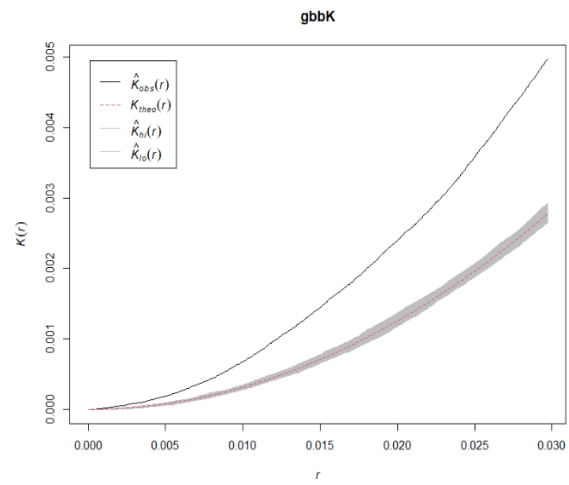
### APPENDIX S1

Table S1.1. Information about the African ape data from the IUCN SSC A.P.E.S. database. Also, the number of ape occurrences and the distance (km) between points considered after checking spatial autocorrelation, and the size (km) of the geographical thinning layer (bias correction) and buffers bounding IUCN range polygons are shown.

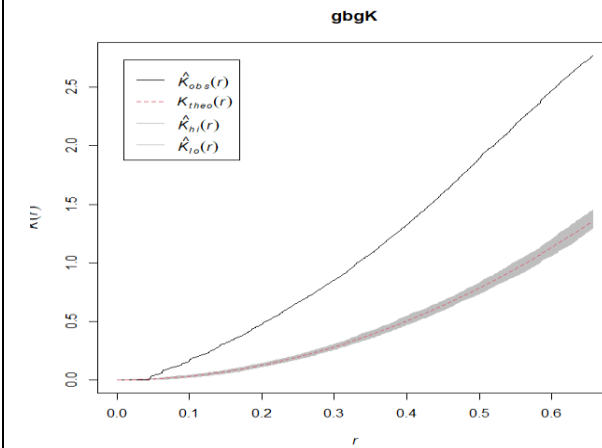
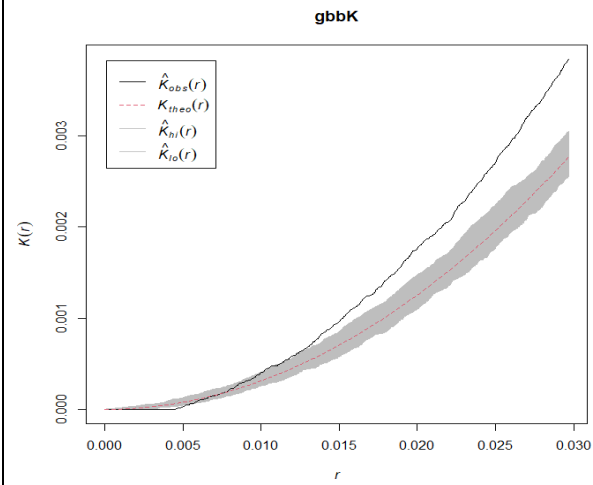
Species	Subspecies	Temporal coverage	Evidence*	No. all occurrences	No. rarefied occurrences	Spatial autocorrelation/ Bias layer**	Buffer
<i>Gorilla</i>	<i>beringei</i>	2002 & 2006	DO, Du, Ne, Tr	266	123	0.5	20
<i>beringei</i>	<i>graueri</i>	2002→2014	Du, FR, FP, Ne, Vo	1,869	221	5	50
<i>Gorilla gorilla</i>	<i>diehli</i>	1998→2013	DO, Du, FR, FP, Ne, Tr, RP, Vo	909	87	1	50
	<i>gorilla</i>	2001→2016	DO, Du, FR, FP, Ne, Tr, Vo	18,723	1,521	5	50
<i>Pan paniscus</i>		2004→2012	DO, Du, FR, FP, Ne, Tr, Vo	4,683	600	5	50
<i>Pan troglodytes</i>	<i>elliotti</i>	1998→2015	DO, Du, FR, FP, Ne, Pl, Tr, RP, Vo	1,222	122	5	50
	<i>schweinfurthii</i>	1999→2014	DO, Du, FR, FP, Ne, Vo	12,294	512	5	70
	<i>troglodytes</i>	1998→2015	DO, Du, FR, FP, Ne, Tr, Vo	13,020	1,293	5	50
	<i>verus</i>	1998→2017	DO, Du, FR, FP, Ne, Tr, Vo	14,166	724	5	200

\* DO - Direct observation, Du – Dung, FR - Feeding remains, FP – Footprint, Ne – Nest, Pl- Playground, RP - Resting place, Tr - Trail/passage, Vo – Vocalization; \*\* Geographical thinning performed best for all species (see methods, Fig. S1.2).

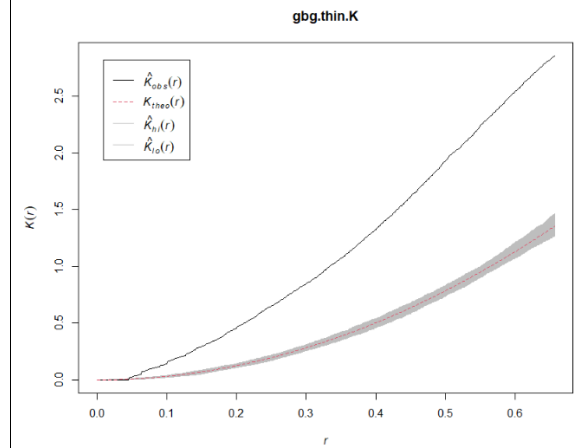
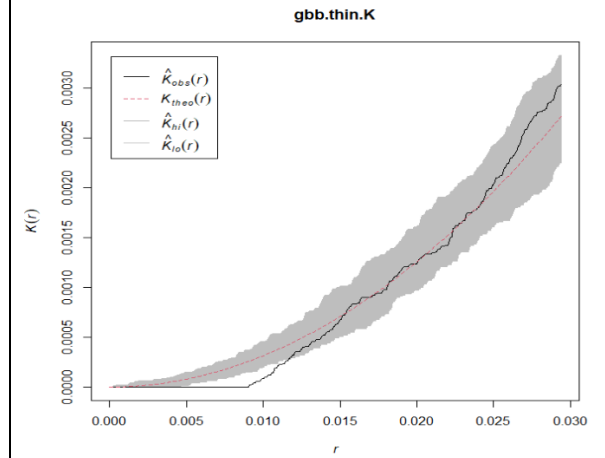
a) All occurrences

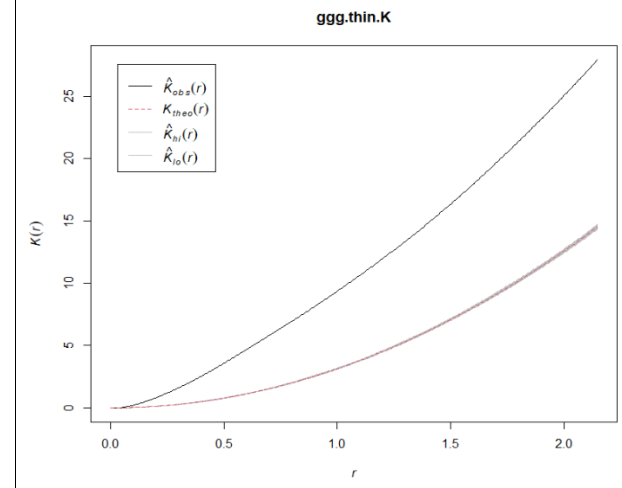
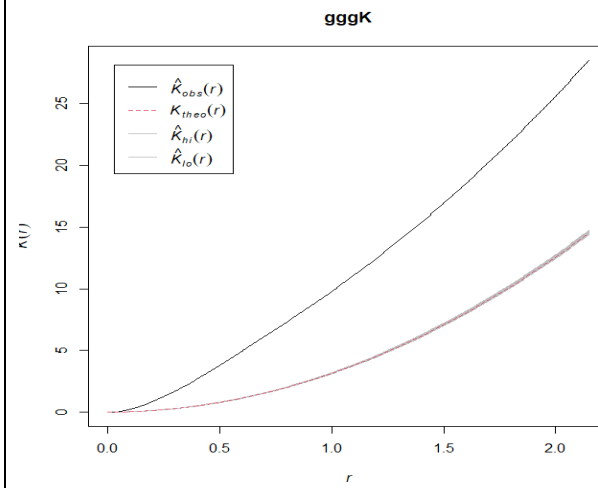
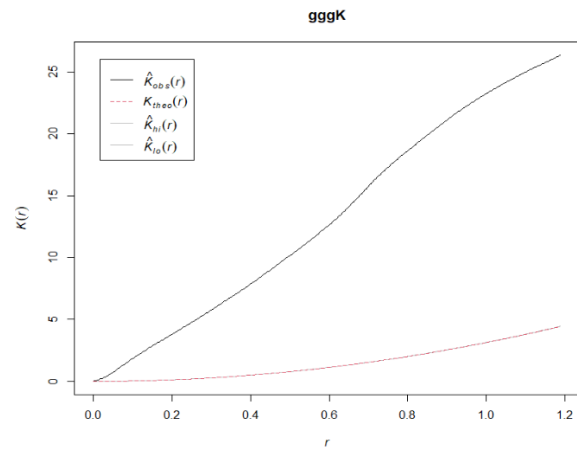
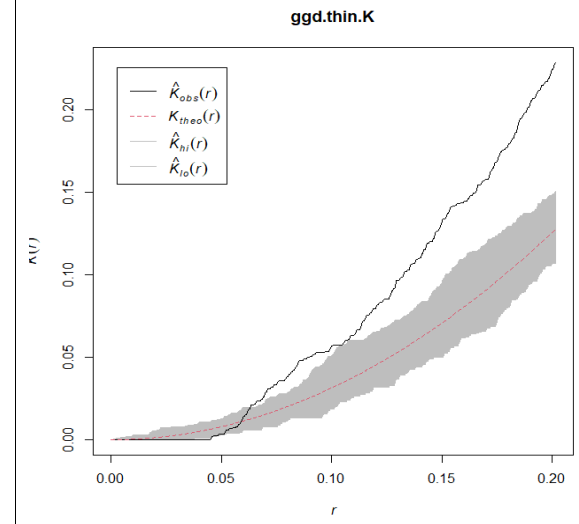
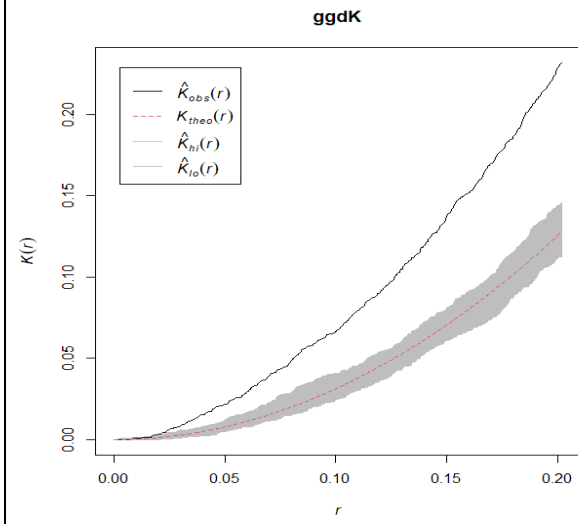
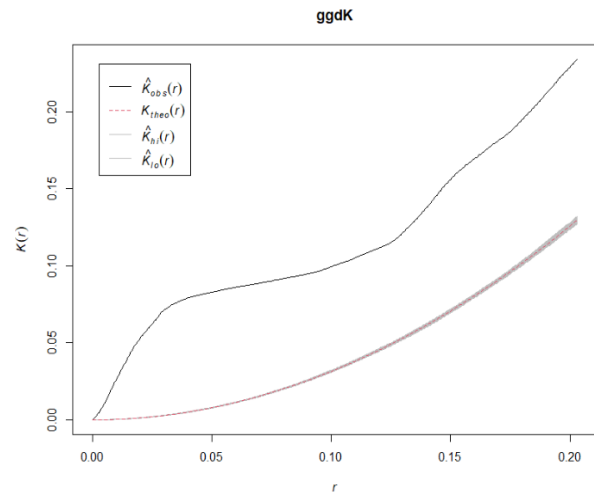


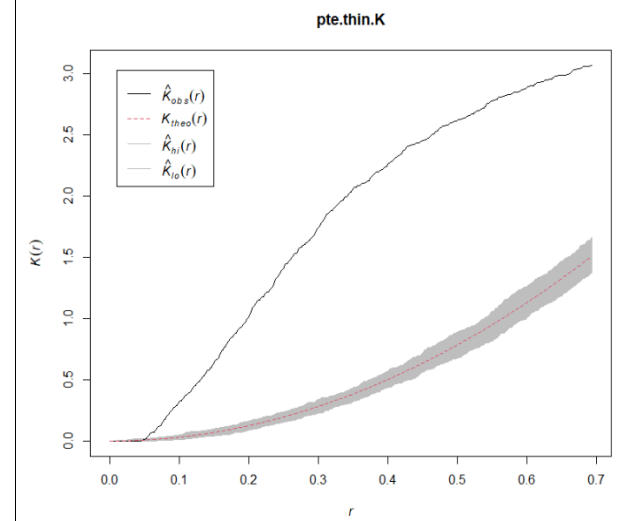
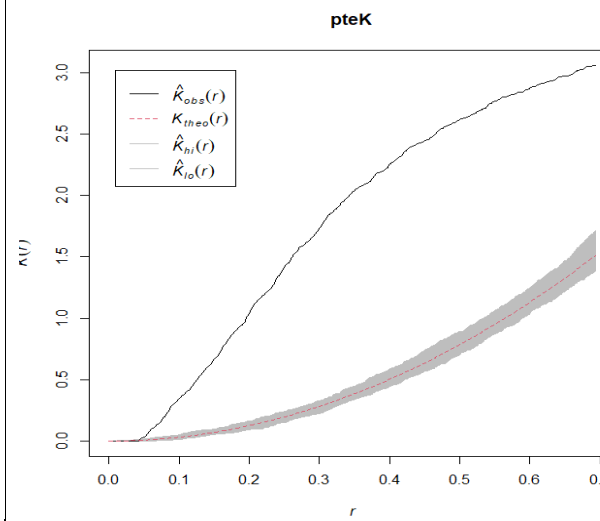
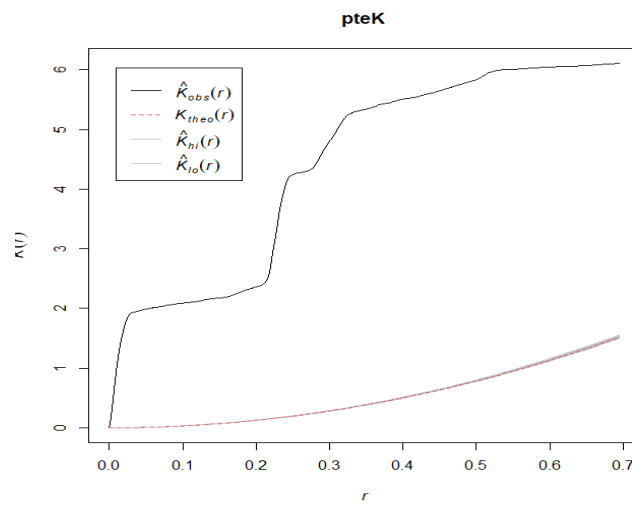
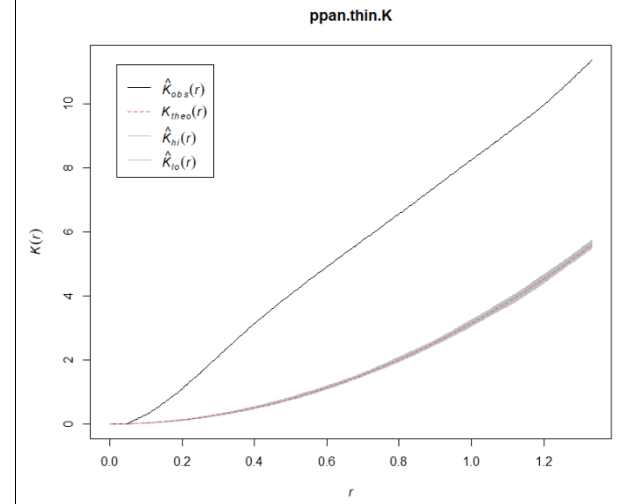
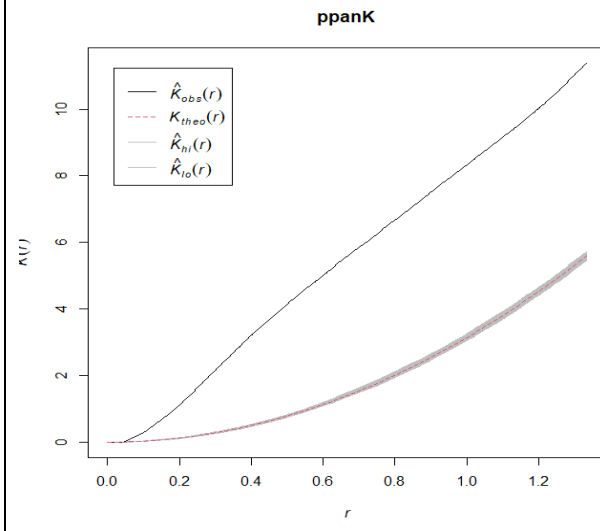
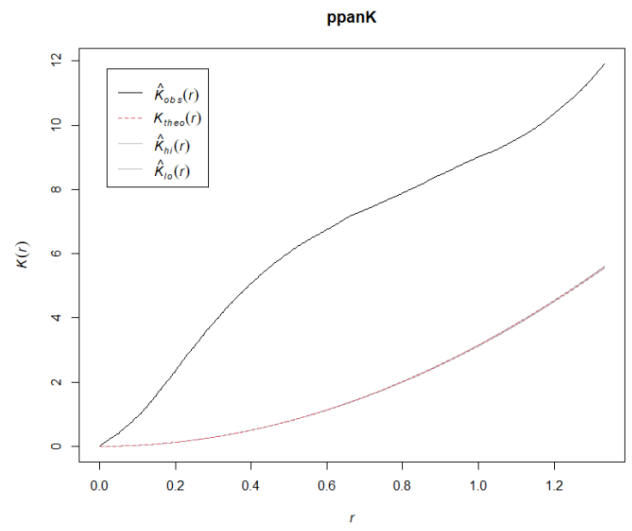
b) Rarefied occurrences

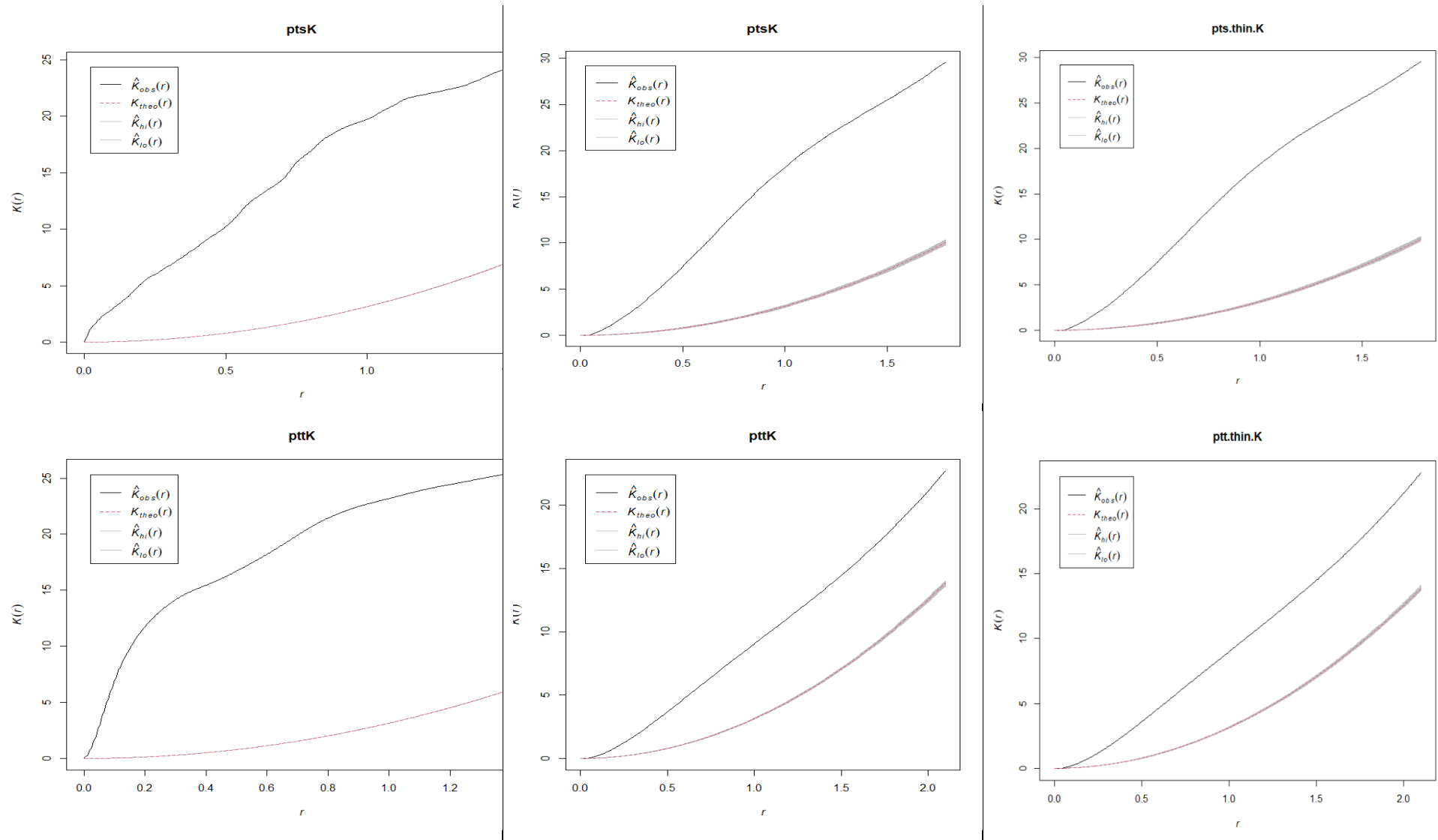


c) Geographic thinning bias layer









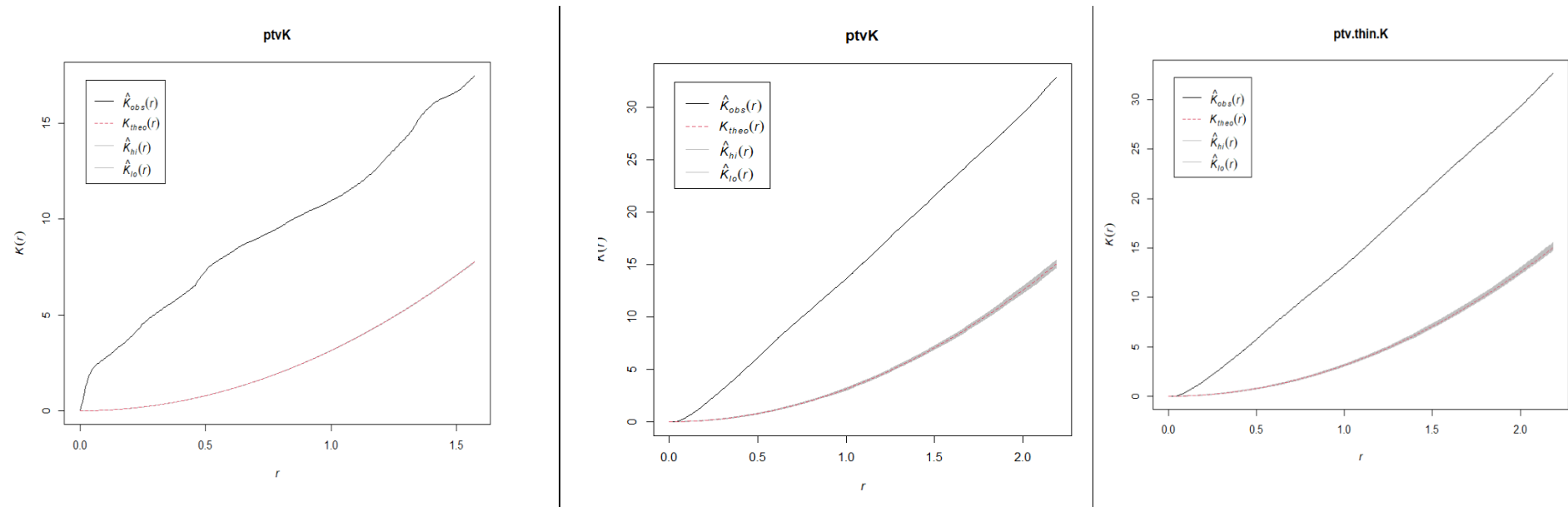
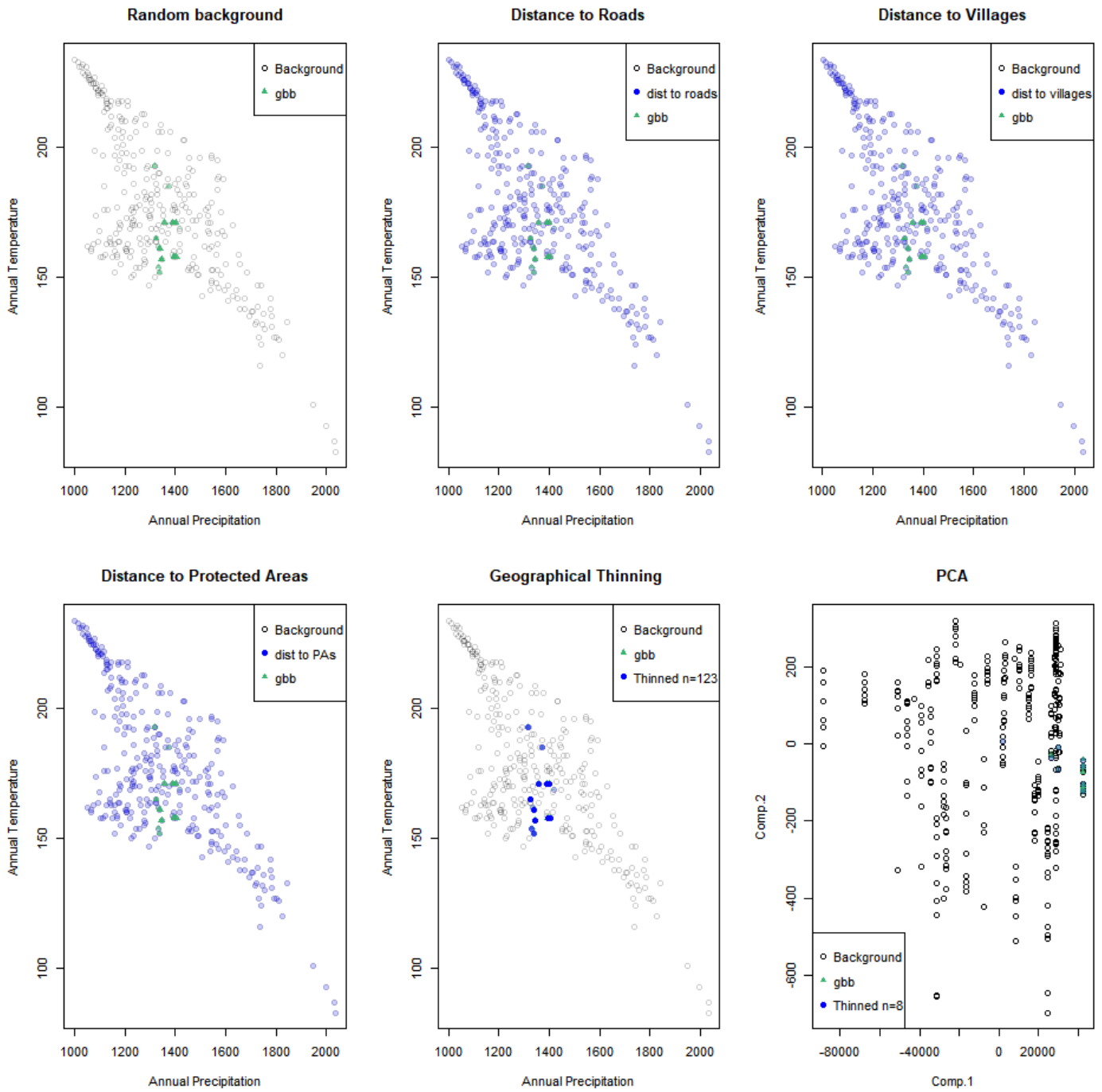
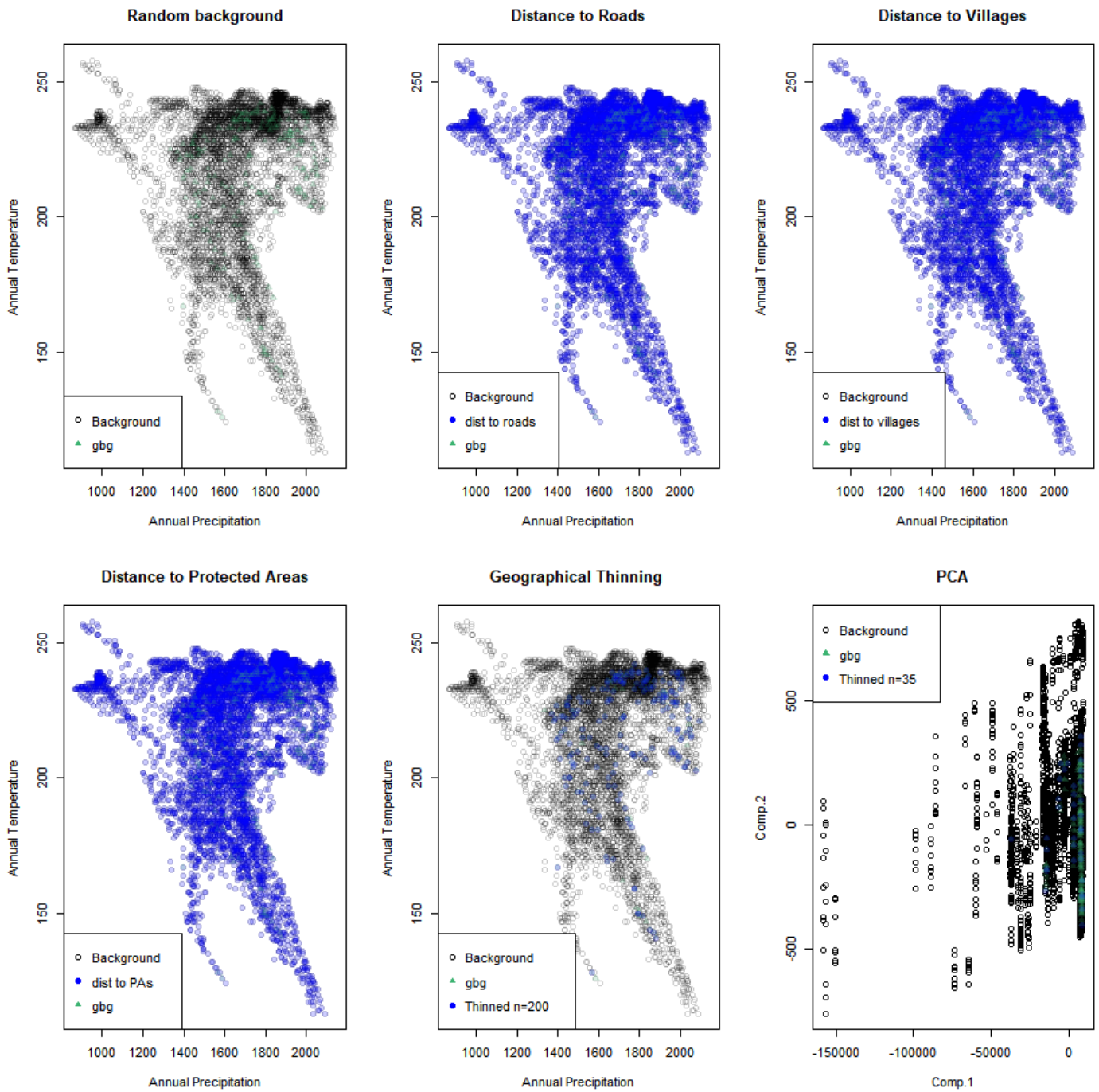


Fig. S1.1. Plots of the Ripley's K-function for a) all occurrence points, b) only occurrence points at a certain distance (for details on the distances used for each taxon see Table S1.1), and c) geographic thinning bias layer (see Table S1.1 for more details). If the observed  $\hat{K}(r)$  function falls above the envelope (grey band), indicates that the presence points are highly clumped at every distance, but if the observed  $\hat{K}(r)$  function is within the envelope, indicates that the presence points follow complete spatial randomness at every distance, which suggests that there is not clear clumping or repelling pattern in the dataset. The high and low  $\hat{K}(r)$  functions represent significance bands. Species name abbreviations: gbb – *Gorilla beringei beringei*, gbg – *G. b. graueri*, ggd – *Gorilla gorilla diehli*, ggg – *G. g. gorilla*, ppan – *Pan paniscus*, pte – *Pan troglodytes ellioti*, pts – *P. t. schweinfurthii*, ptt – *P. t. troglodytes*, ptv – *P. t. verus*.

*Gorilla beringei beringei*

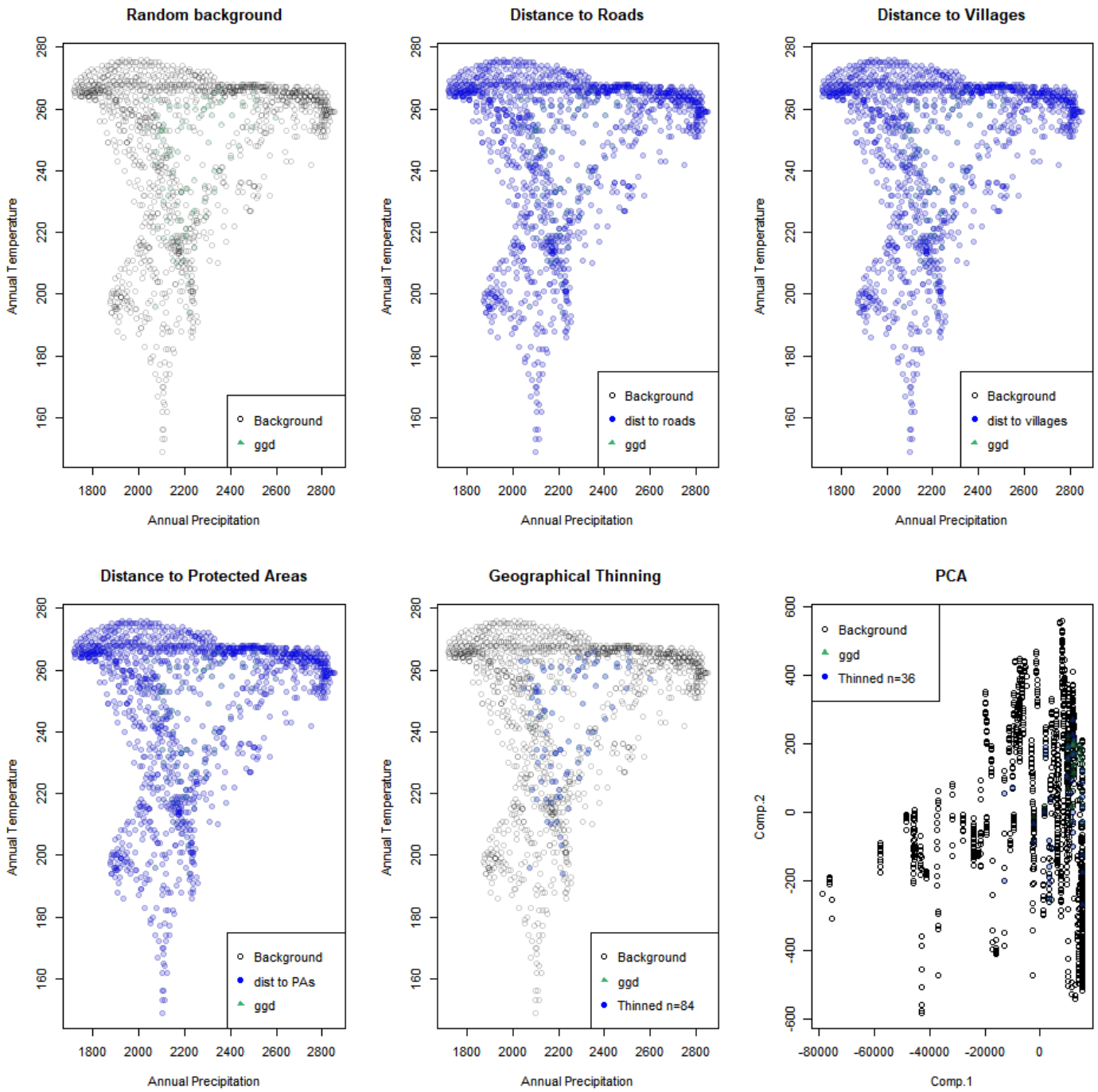


*Gorilla beringei graueri*

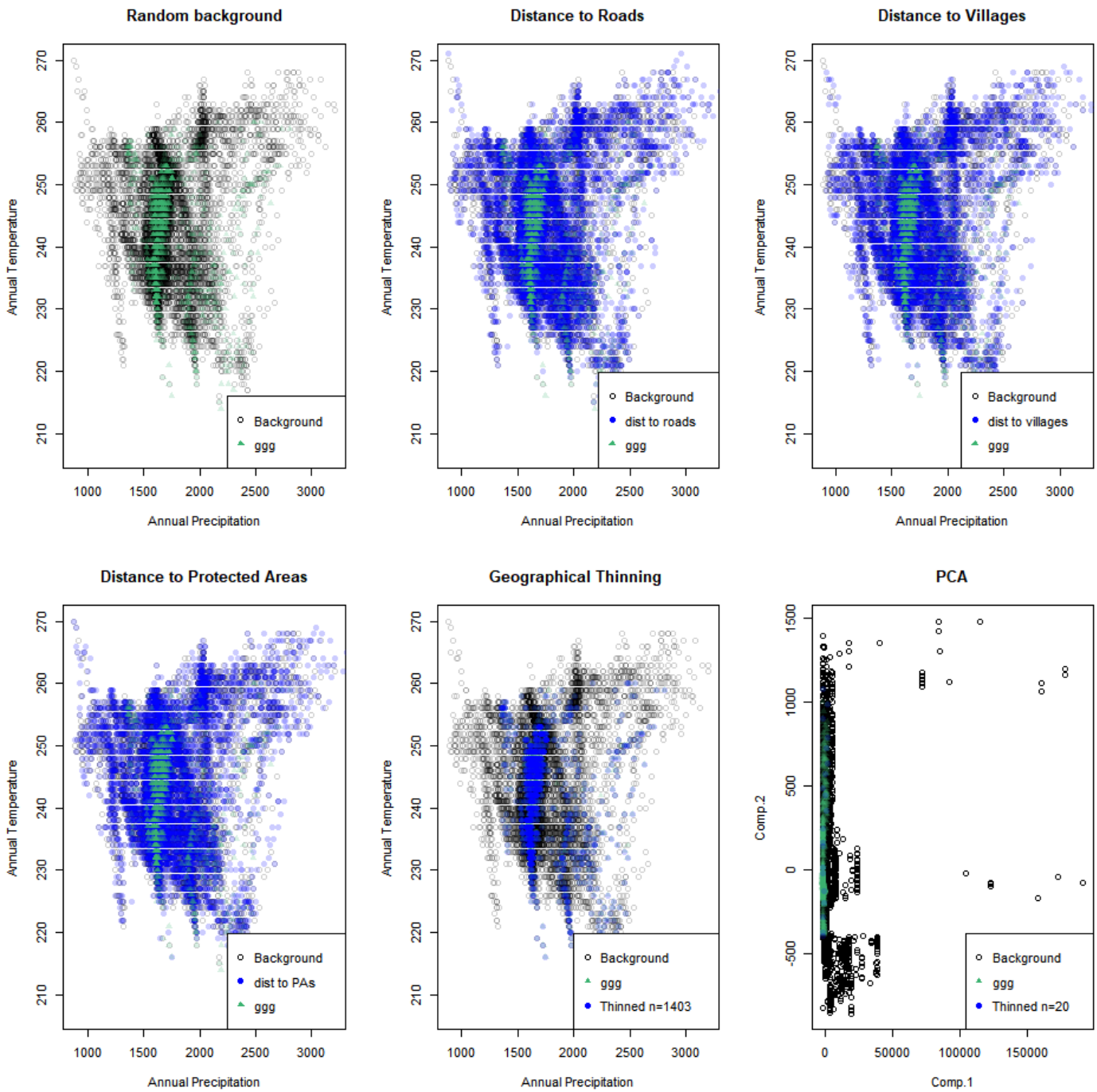




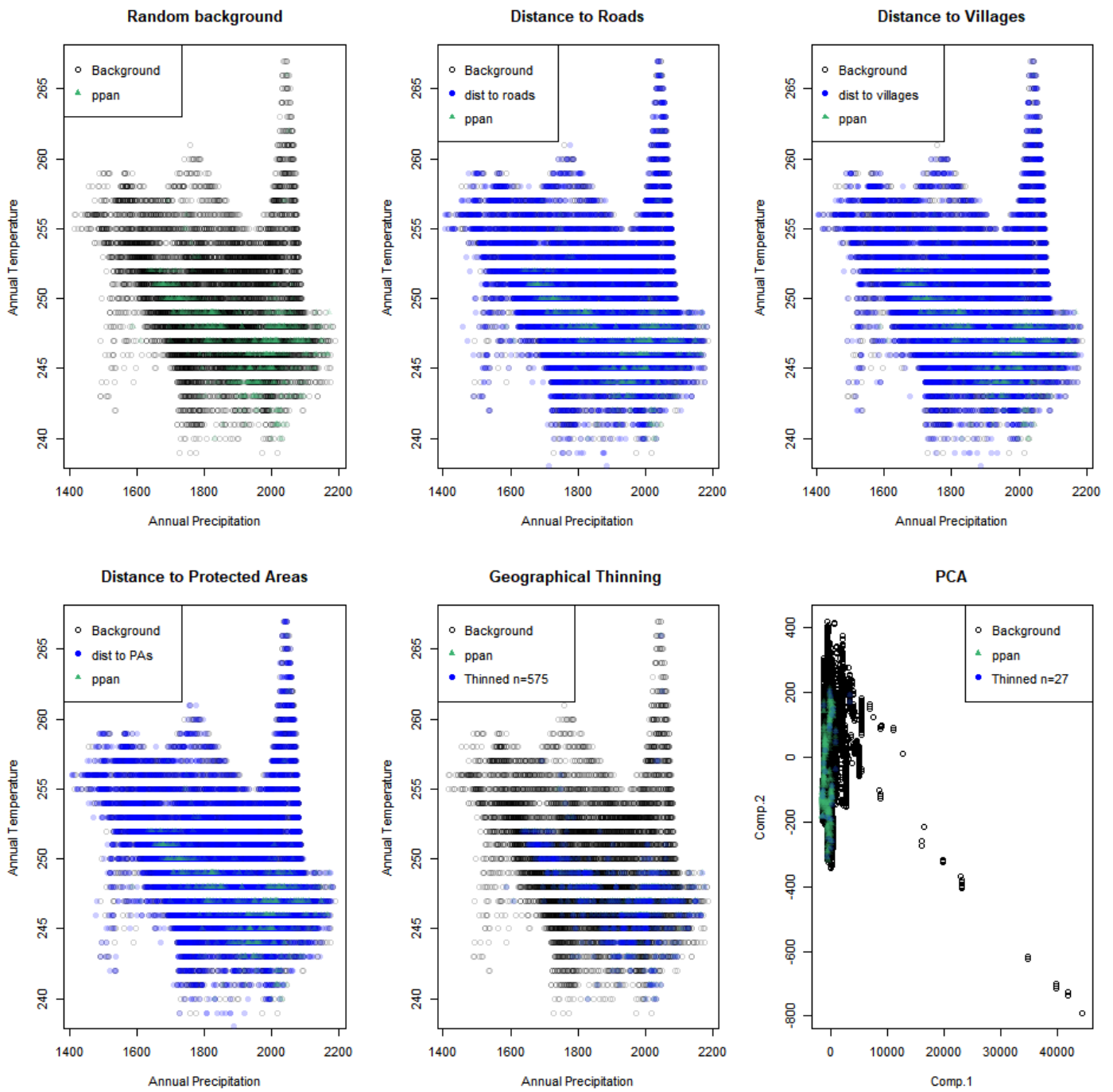
*Gorilla gorilla diehli*



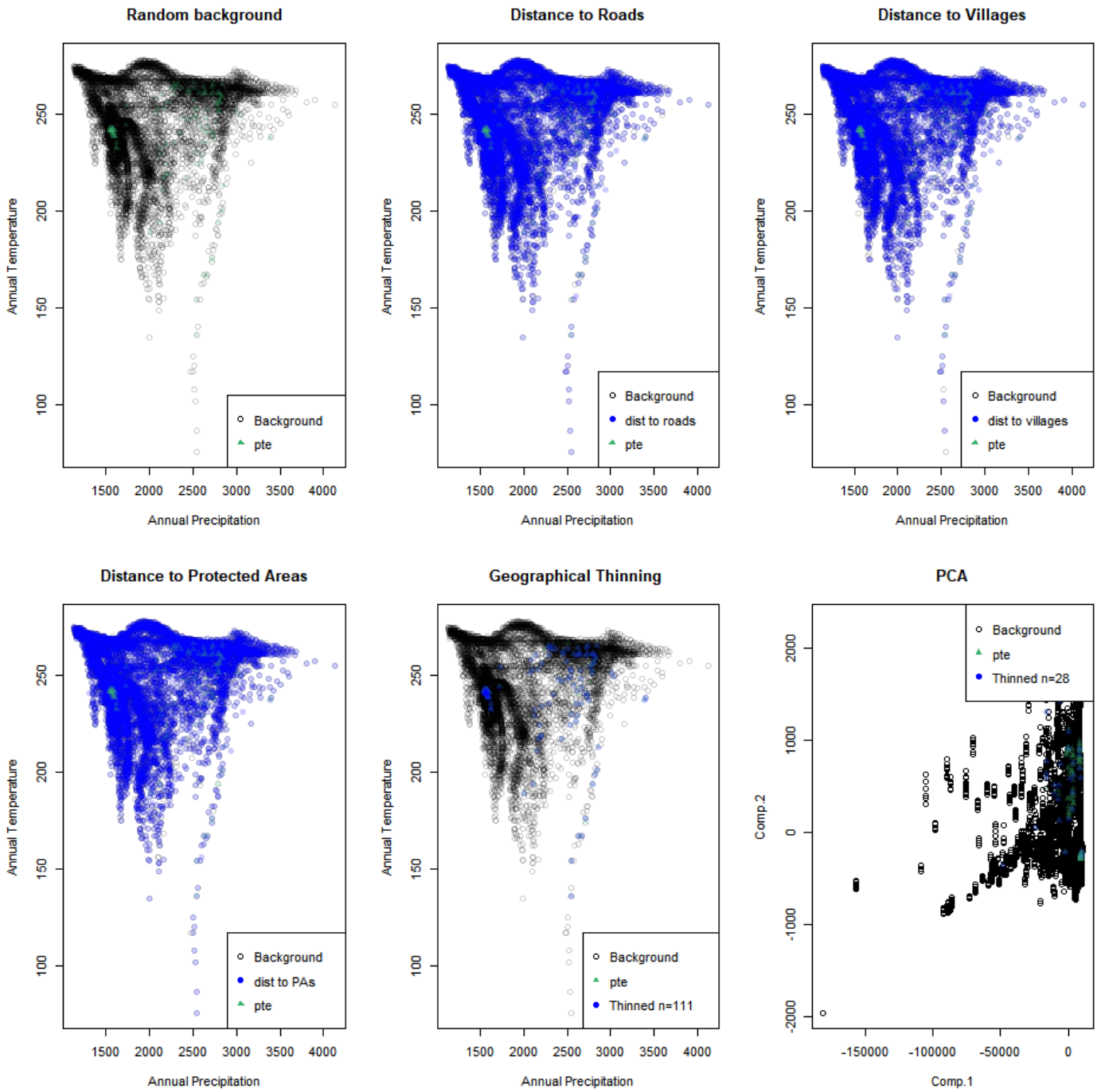
*Gorilla gorilla gorilla*



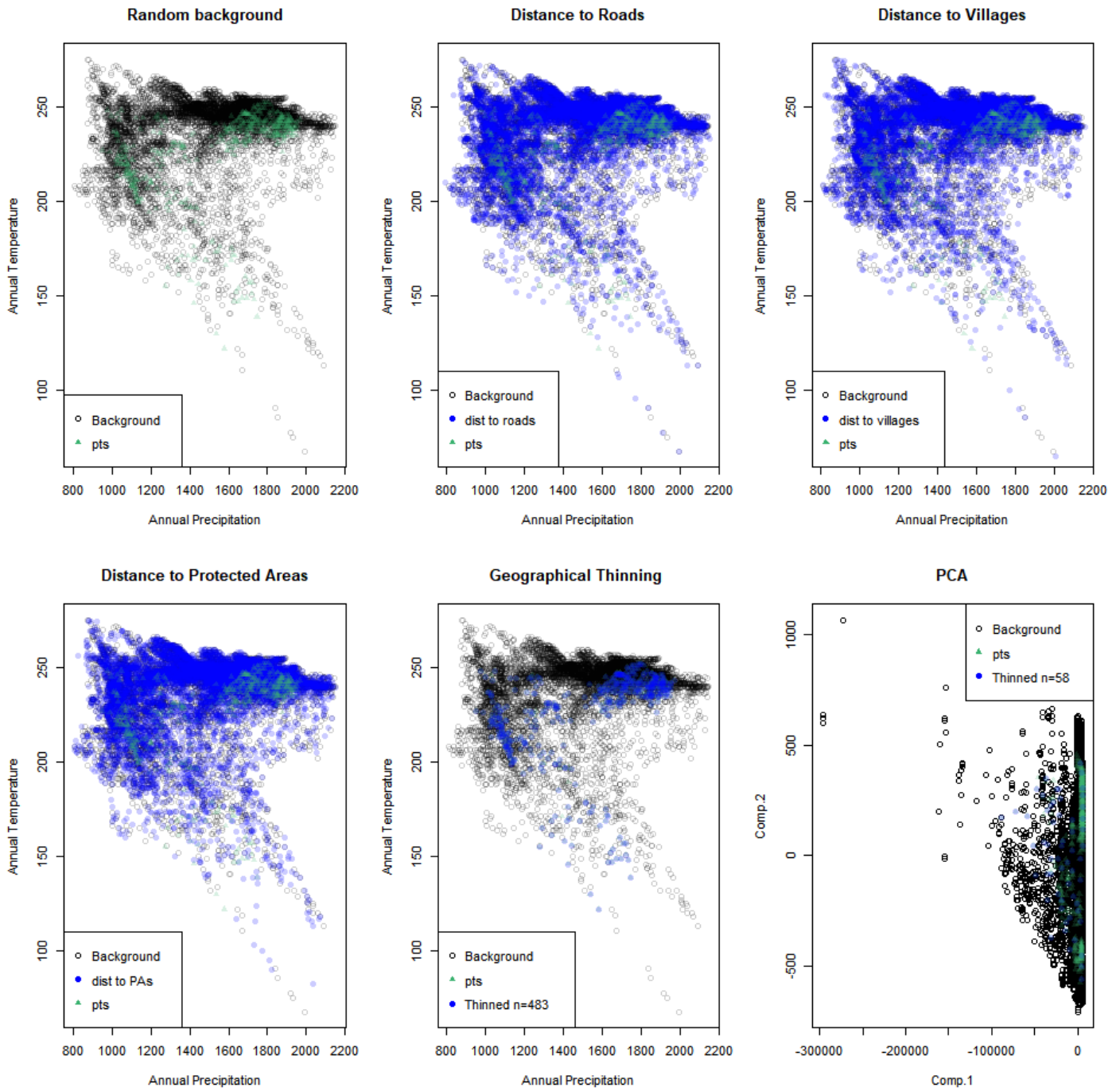
*Pan paniscus*



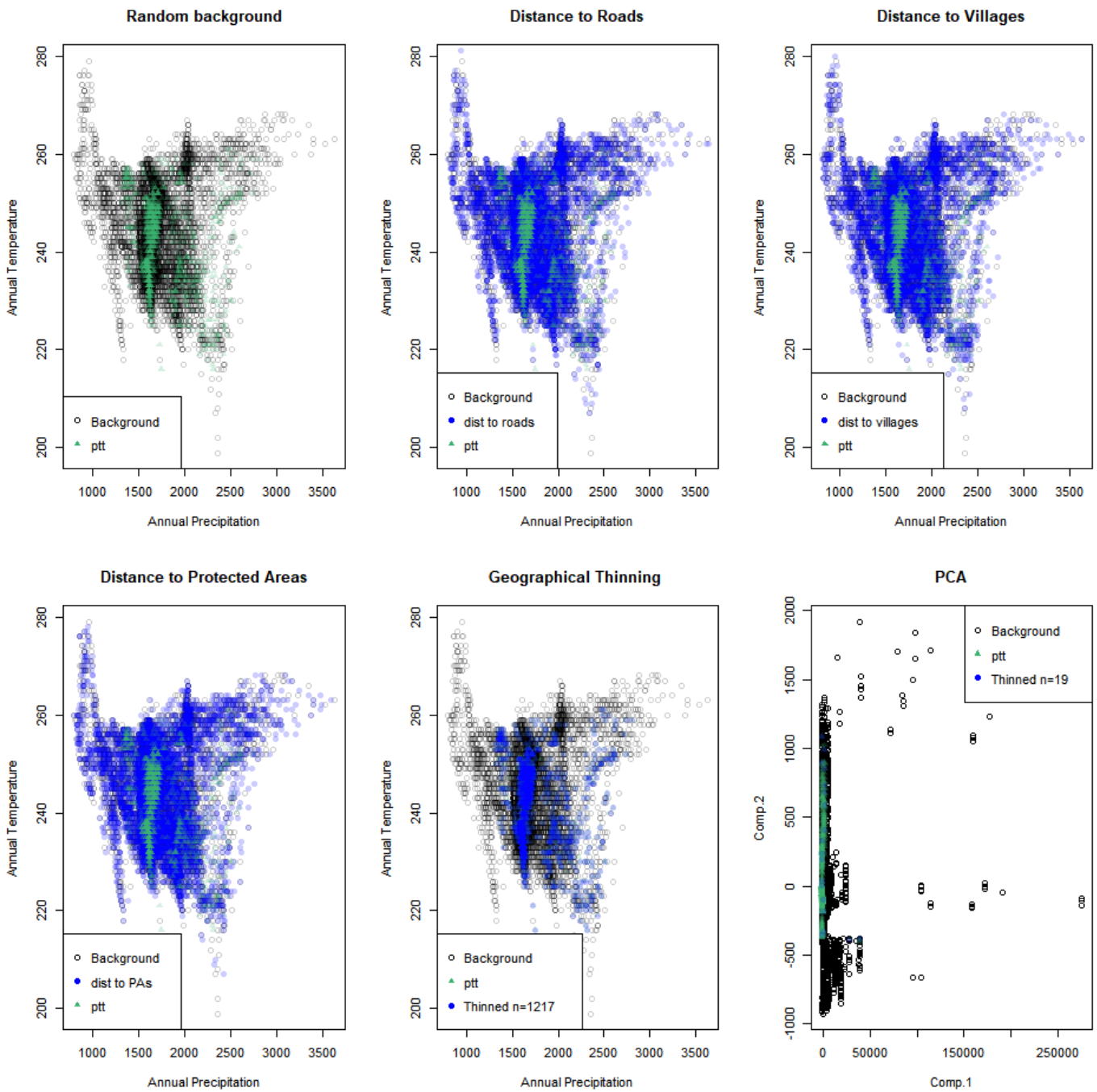
*Pan troglodytes ellioti*



*Pan troglodytes schweinfurthii*



*Pan troglodytes troglodytes*



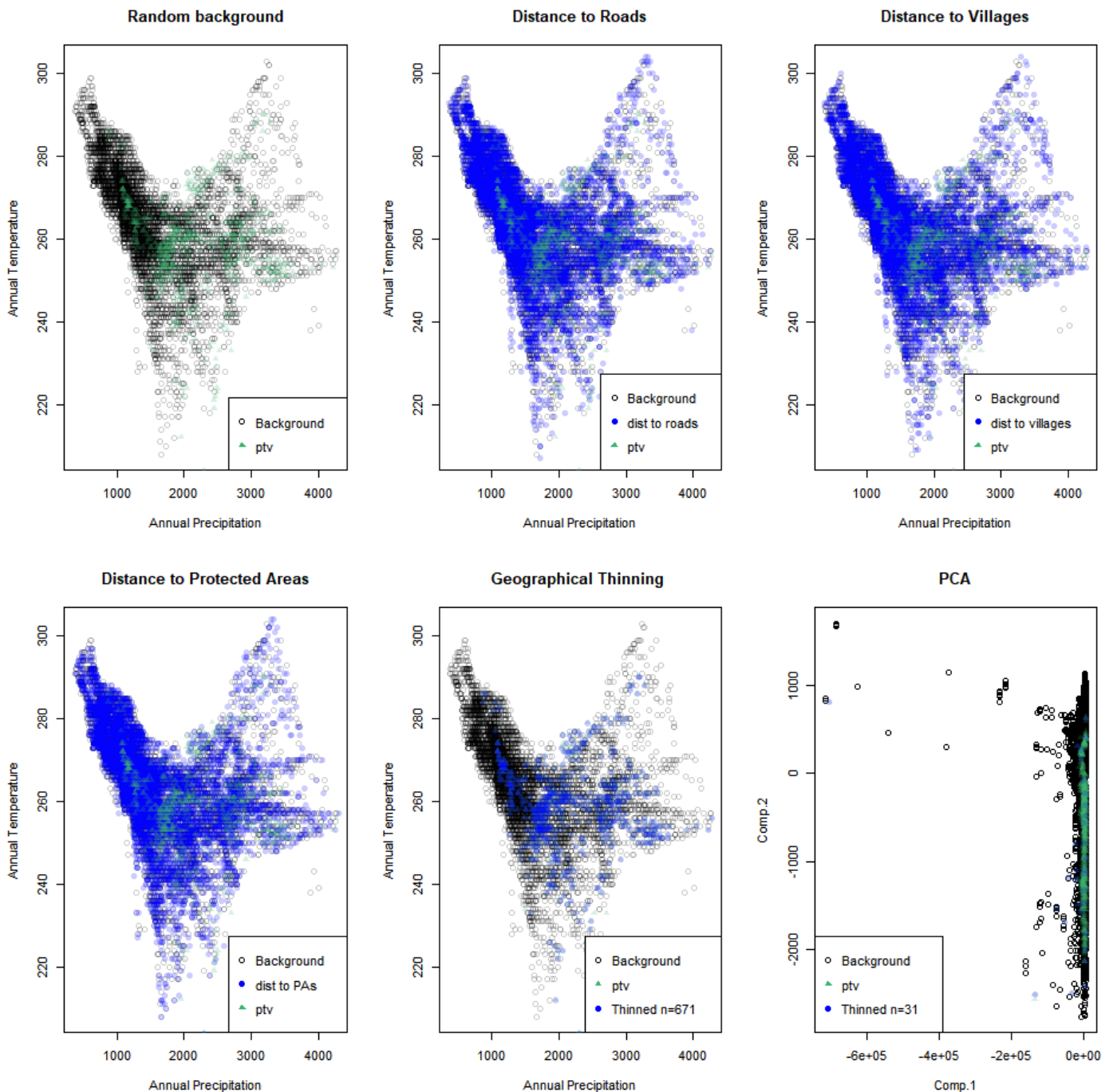
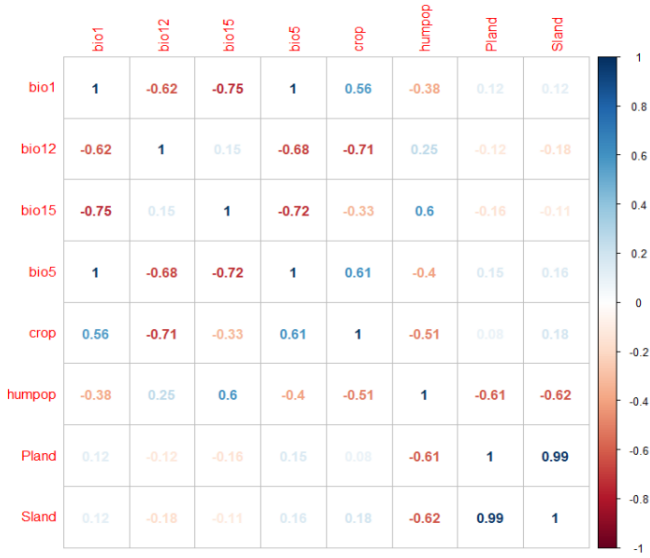
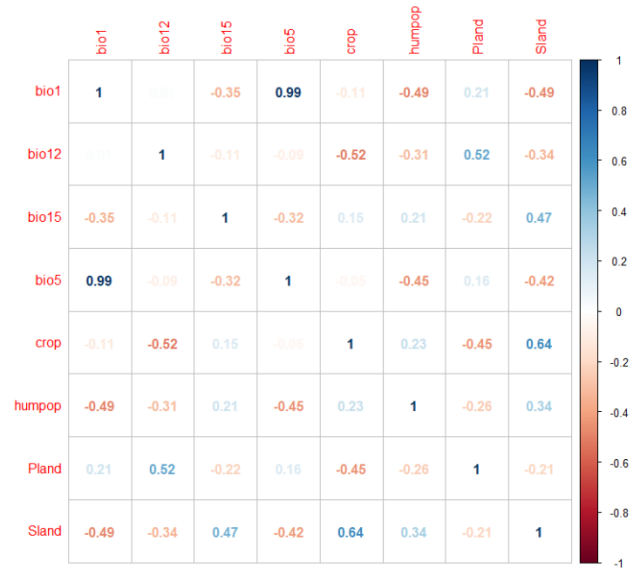
*Pan troglodytes verus*

Figure S1.2. Plots of the sampling bias based on different methods of bias correction for each taxon. For each taxon, only annual temperature and annual precipitation are plotted and the best approach to sampling bias correction was selected based on the greatest overlap between the predictor values of sampling bias over the species occurrences (only rarefied points were used, see Table S1.1). Given that geographic thinning approach performed best for all taxa, it was integrated into the SDMs for sampling bias correction. White circles – random background data, blue circles – sampling bias data, and green triangles – taxon evidences. See methods section for more details. See more examples at <http://www.earthskysea.org/workshops-classes/>

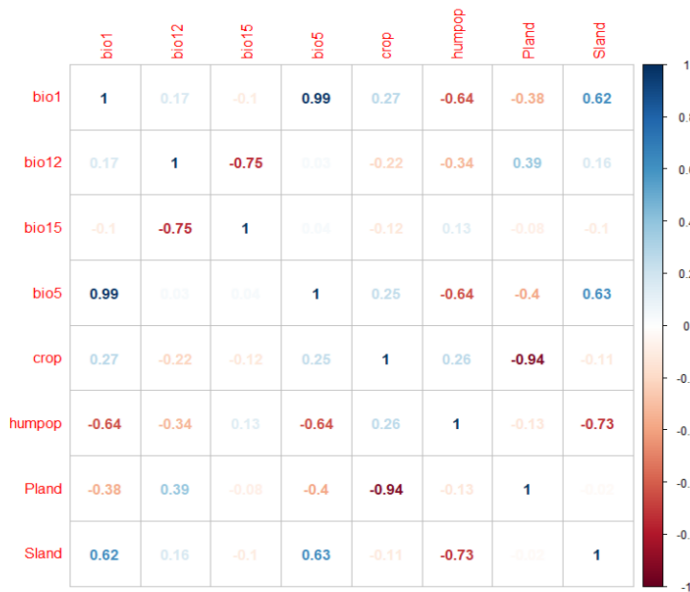
*Gorilla beringei beringei*



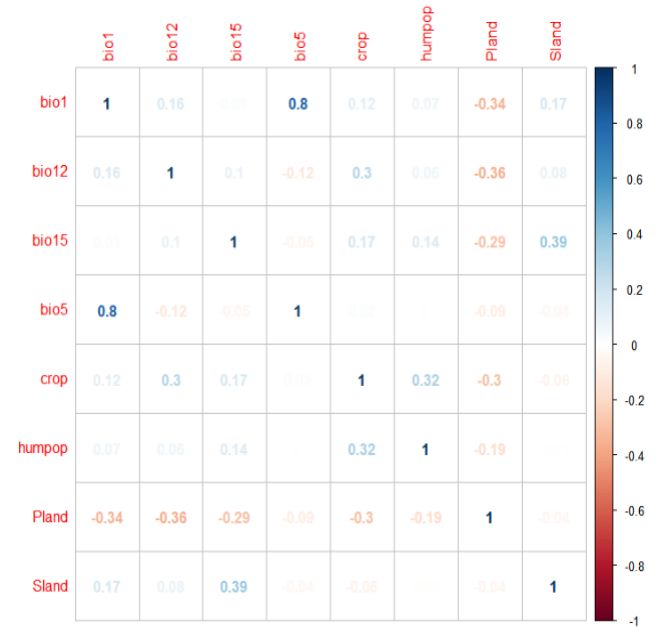
*Gorilla beringei graueri*



*Gorilla gorilla diehli*

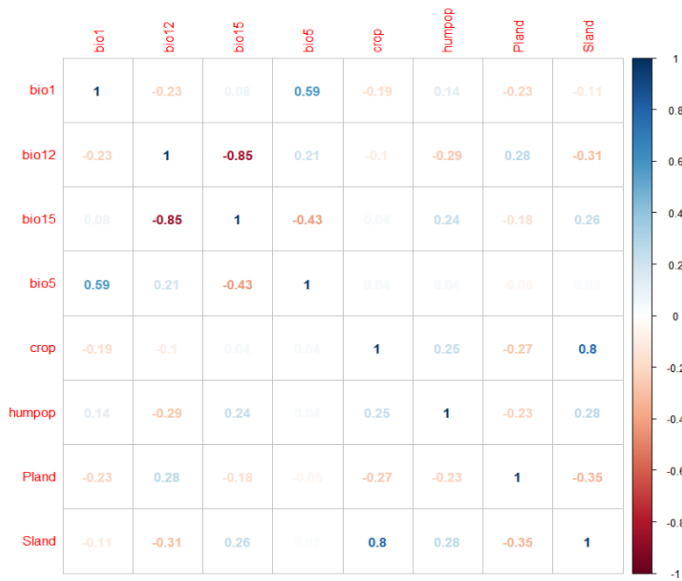


*Gorilla gorilla gorilla*

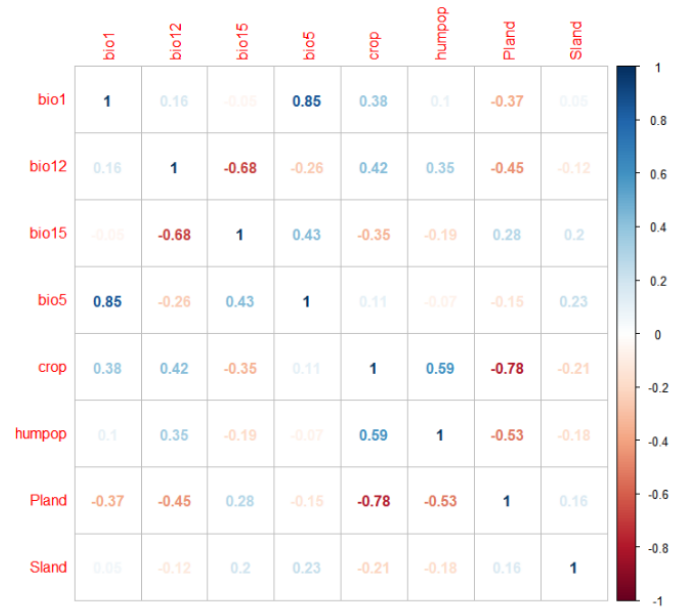




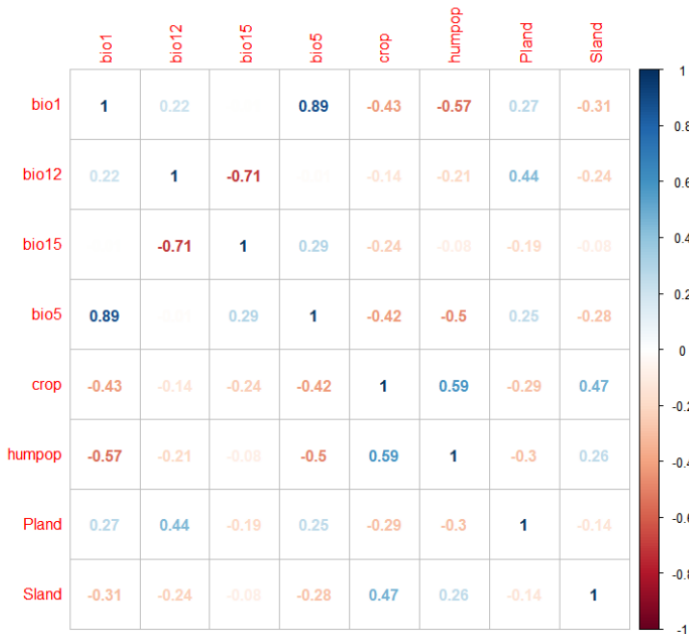
*Pan paniscus*



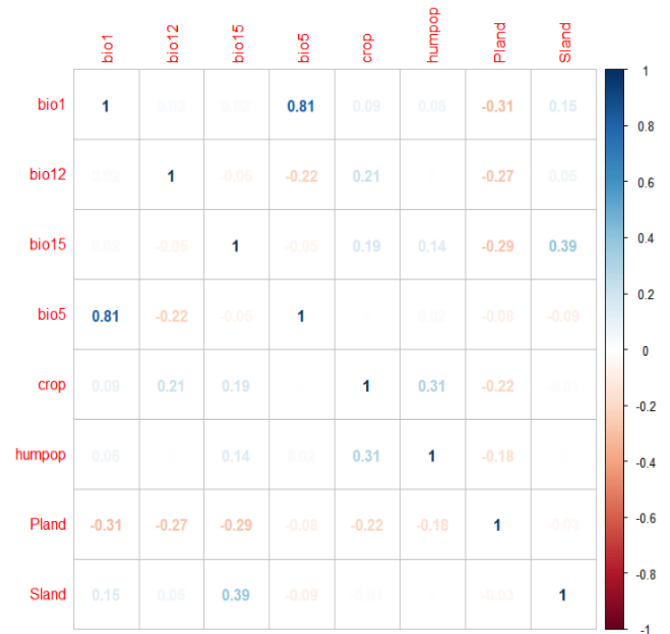
*Pan troglodytes ellioti*



*Pan troglodytes schweinfurthii*



*Pan troglodytes troglodytes*



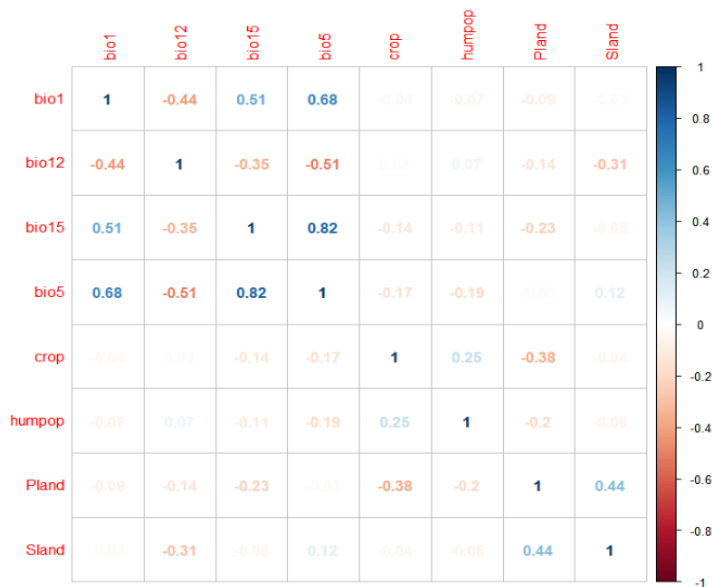
*Pan troglodytes verus*

Figure S1.3. Results of Pearson correlations between all predictor variables for each taxon. Positive correlations are displayed in blue and negative correlations in red colour. Colour intensity is proportional to the correlation coefficients.

Table S1.2. Taxon-specific PCA loadings obtained for the first four axis. The respective proportion of total variance and cumulative proportion are also shown. For each PCA axis, only loadings  $> |0.4|$  are marked in bold.

<i>Gorilla beringei beringei</i>				
Variables	PC1	PC2	PC3	PC4
annual temperature	<b>-0.449</b>	-0.306	0.146	-0.199
annual precipitation	0.324	0.206	<b>0.629</b>	0.323
precipitation seasonality	0.107	<b>0.568</b>	-0.315	-0.247
maximum temperature	<b>-0.464</b>	-0.276	0.084	-0.207
cropland	<b>-0.439</b>	0.251	-0.132	<b>0.406</b>
human population	-0.187	<b>0.500</b>	0.038	<b>-0.536</b>
primary land	0.287	-0.276	<b>-0.652</b>	0.097
secondary land	<b>0.396</b>	-0.276	0.179	<b>-0.539</b>
Proportion of Variance	0.450	0.285	0.130	0.085
Cumulative Proportion	0.450	0.735	0.865	0.950

<i>Gorilla beringei graueri</i>				
Variables	PC1	PC2	PC3	PC4
annual temperature	<b>-0.636</b>	-0.046	0.065	-0.108
annual precipitation	-0.015	0.314	<b>0.483</b>	<b>0.501</b>
precipitation seasonality	0.271	-0.354	0.052	<b>-0.623</b>
maximum temperature	<b>-0.629</b>	-0.094	0.016	-0.167
cropland	-0.131	<b>-0.507</b>	-0.335	0.335
human population	0.266	<b>-0.435</b>	-0.078	0.368
primary land	0.150	<b>0.541</b>	<b>-0.414</b>	-0.185
secondary land	0.122	-0.159	<b>0.685</b>	-0.198
Proportion of Variance	0.290	0.233	0.186	0.104
Cumulative Proportion	0.290	0.522	0.709	0.813

<i>Gorilla gorilla diehli</i>				
Variables	PC1	PC2	PC3	PC4
annual temperature	<b>-0.554</b>	0.177	0.008	-0.048
annual precipitation	-0.148	<b>0.414</b>	<b>-0.481</b>	0.297
precipitation seasonality	-0.174	<b>-0.408</b>	<b>0.447</b>	<b>-0.371</b>
maximum temperature	<b>-0.559</b>	0.110	0.055	-0.148
cropland	-0.367	-0.386	<b>-0.403</b>	-0.107
human population	0.070	<b>-0.485</b>	0.064	<b>0.674</b>
primary land	<b>0.433</b>	0.093	-0.261	<b>-0.503</b>
secondary land	0.005	<b>0.476</b>	<b>0.575</b>	0.174
Proportion of Variance	0.344	0.262	0.173	0.101
Cumulative Proportion	0.344	0.606	0.779	0.880

<i>Gorilla gorilla gorilla</i>				
Variables	PC1	PC2	PC3	PC4
annual temperature	<b>0.544</b>	-0.264	0.134	-0.069
annual precipitation	0.056	0.320	0.308	<b>-0.872</b>
precipitation seasonality	0.121	<b>0.519</b>	-0.379	0.019
maximum temperature	<b>0.506</b>	-0.361	0.106	0.054
cropland	0.258	-0.191	<b>-0.476</b>	-0.330
human population	0.105	0.067	<b>-0.681</b>	-0.077
primary land	<b>-0.520</b>	-0.238	-0.083	-0.111
secondary land	0.286	<b>0.574</b>	0.187	0.323
Proportion of Variance	0.339	0.179	0.153	0.117
Cumulative Proportion	0.339	0.517	0.670	0.787

<i>Pan paniscus</i>				
Variables	PC1	PC2	PC3	PC4
annual temperature	<b>0.462</b>	-0.114	0.261	-0.066
annual precipitation	-0.036	<b>-0.677</b>	-0.175	0.057
precipitation seasonality	0.111	<b>0.657</b>	0.170	-0.115
maximum temperature	<b>0.457</b>	-0.232	0.204	-0.065
cropland	0.361	-0.086	<b>0.575</b>	0.043
human population	0.278	0.142	-0.210	<b>0.926</b>
primary land	<b>-0.458</b>	-0.012	0.377	0.201
secondary land	0.384	0.123	<b>-0.560</b>	-0.274
Proportion of Variance	0.475	0.237	0.113	0.092
Cumulative Proportion	0.475	0.712	0.824	0.916

<i>Pan troglodytes ellioti</i>				
Variables	PC1	PC2	PC3	PC4
annual temperature	<b>-0.517</b>	-0.124	0.159	<b>-0.423</b>
annual precipitation	0.064	<b>-0.596</b>	0.276	-0.156
precipitation seasonality	-0.222	<b>0.547</b>	-0.237	0.297
maximum temperature	<b>-0.560</b>	0.174	0.029	-0.264
cropland	-0.389	-0.264	<b>-0.422</b>	0.104
human population	-0.172	-0.383	-0.006	<b>0.709</b>
primary land	<b>0.429</b>	0.037	-0.368	-0.310
secondary land	0.029	0.287	<b>0.727</b>	0.169
Proportion of Variance	0.330	0.235	0.179	0.110
Cumulative Proportion	0.330	0.565	0.744	0.854

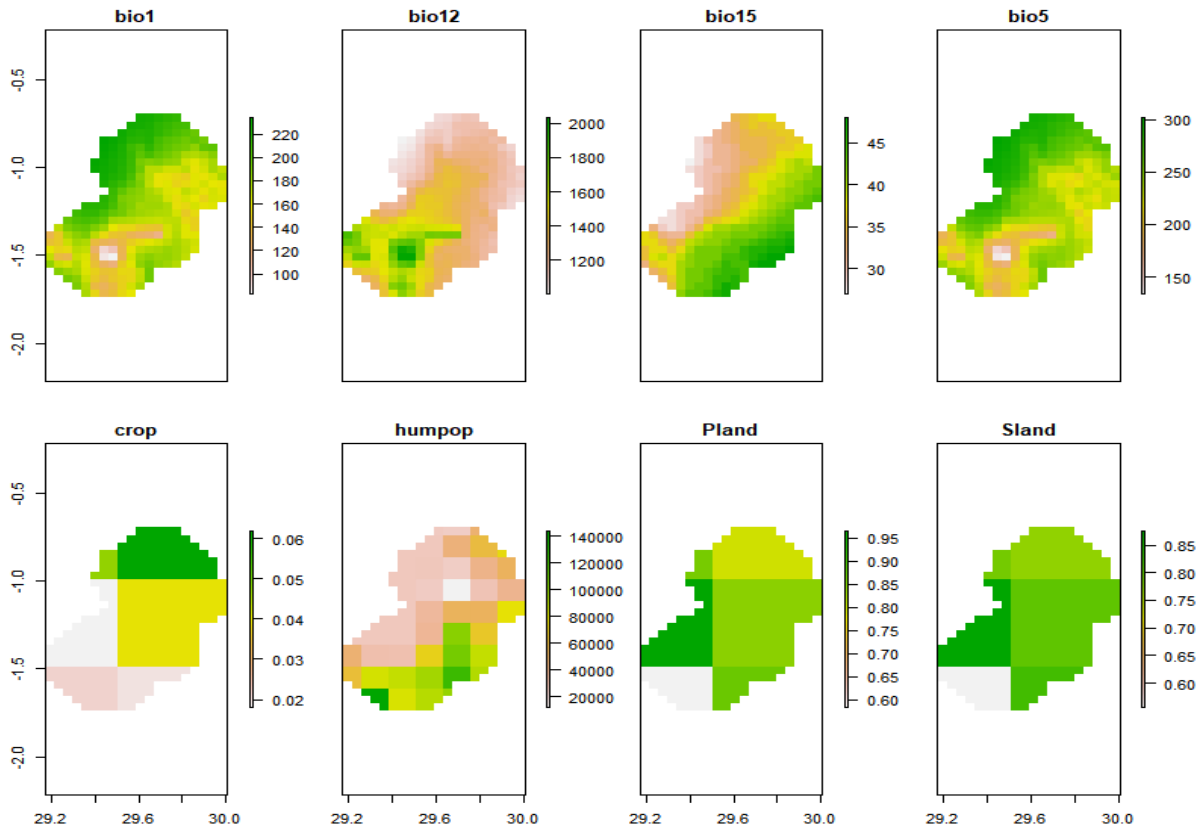
<i>Pan troglodytes schweinfurthii</i>				
Variables	PC1	PC2	PC3	PC4
annual temperature	<b>0.650</b>	-0.017	0.110	-0.121
annual precipitation	0.061	<b>-0.504</b>	<b>0.403</b>	-0.271
precipitation seasonality	0.124	0.347	<b>-0.525</b>	0.336
maximum temperature	<b>0.646</b>	0.077	-0.081	-0.119
cropland	-0.006	<b>0.530</b>	0.225	<b>-0.422</b>
human population	-0.307	<b>0.430</b>	0.235	-0.259
primary land	-0.214	-0.391	<b>-0.466</b>	-0.262
secondary land	-0.011	-0.019	<b>0.470</b>	<b>0.686</b>
Proportion of Variance	0.271	0.246	0.229	0.138
Cumulative Proportion	0.271	0.517	0.746	0.885

<i>Pan troglodytes troglodytes</i>				
Variables	PC1	PC2	PC3	PC4
annual temperature	<b>0.545</b>	0.253	-0.162	0.010
annual precipitation	0.019	-0.319	-0.364	<b>0.817</b>
precipitation seasonality	0.130	<b>-0.449</b>	<b>0.486</b>	-0.195
maximum temperature	<b>0.511</b>	0.354	-0.124	-0.114
cropland	0.266	0.207	<b>0.405</b>	0.381
human population	0.120	-0.016	<b>0.629</b>	0.308
primary land	<b>-0.516</b>	0.266	0.096	0.042
secondary land	0.271	<b>-0.628</b>	-0.140	-0.200
Proportion of Variance	0.545	0.253	-0.162	0.010
Cumulative Proportion	0.019	-0.319	-0.364	0.817

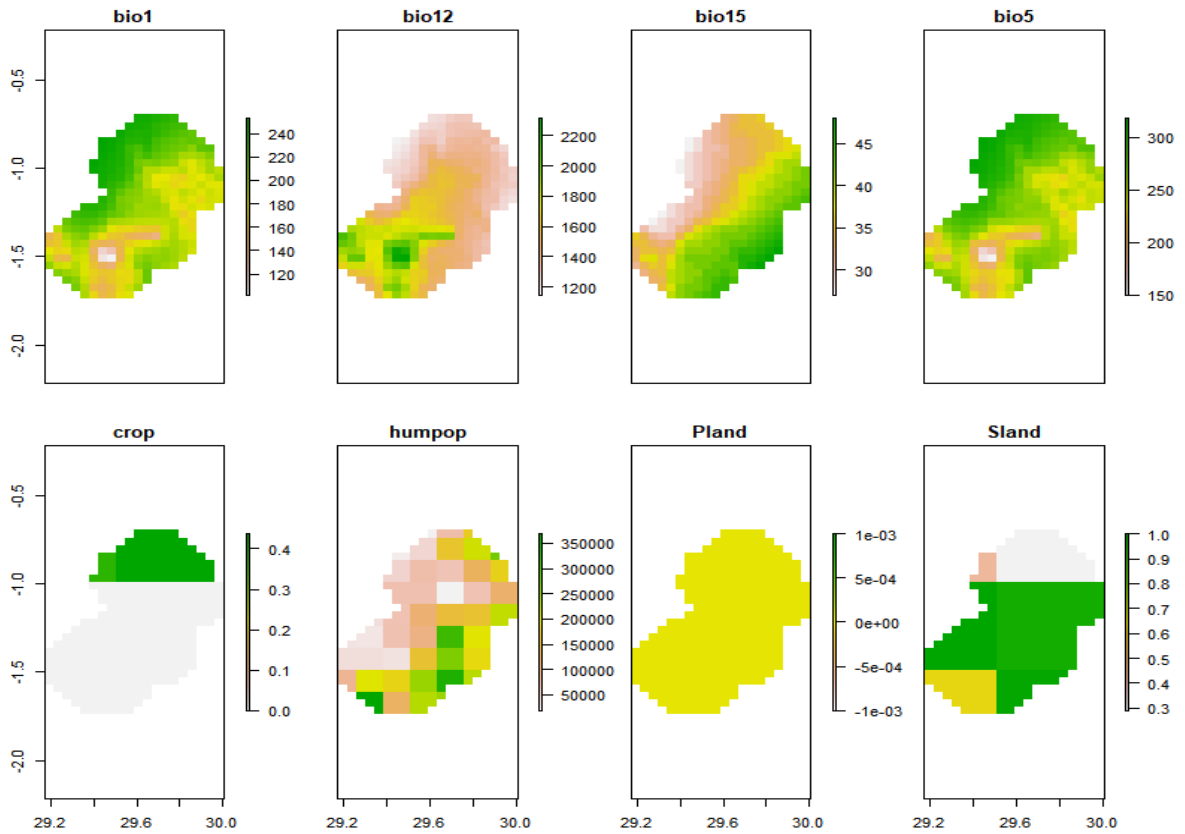
<i>Pan troglodytes verus</i>				
Variables	PC1	PC2	PC3	PC4
annual temperature	<b>-0.511</b>	0.014	-0.162	0.119
annual precipitation	0.318	0.201	<b>-0.474</b>	<b>0.527</b>
precipitation seasonality	-0.317	<b>-0.472</b>	0.179	0.197
maximum temperature	<b>-0.467</b>	-0.335	-0.031	0.136
cropland	-0.213	<b>0.556</b>	0.102	-0.364
human population	-0.039	0.347	<b>0.703</b>	<b>0.607</b>
Primary land	0.355	-0.287	<b>0.459</b>	-0.326
Secondary land	0.383	-0.336	-0.009	0.210
Proportion of Variance	0.397	0.240	0.113	0.106
Cumulative Proportion	0.397	0.637	0.750	0.856

*Gorilla beringei beringei*

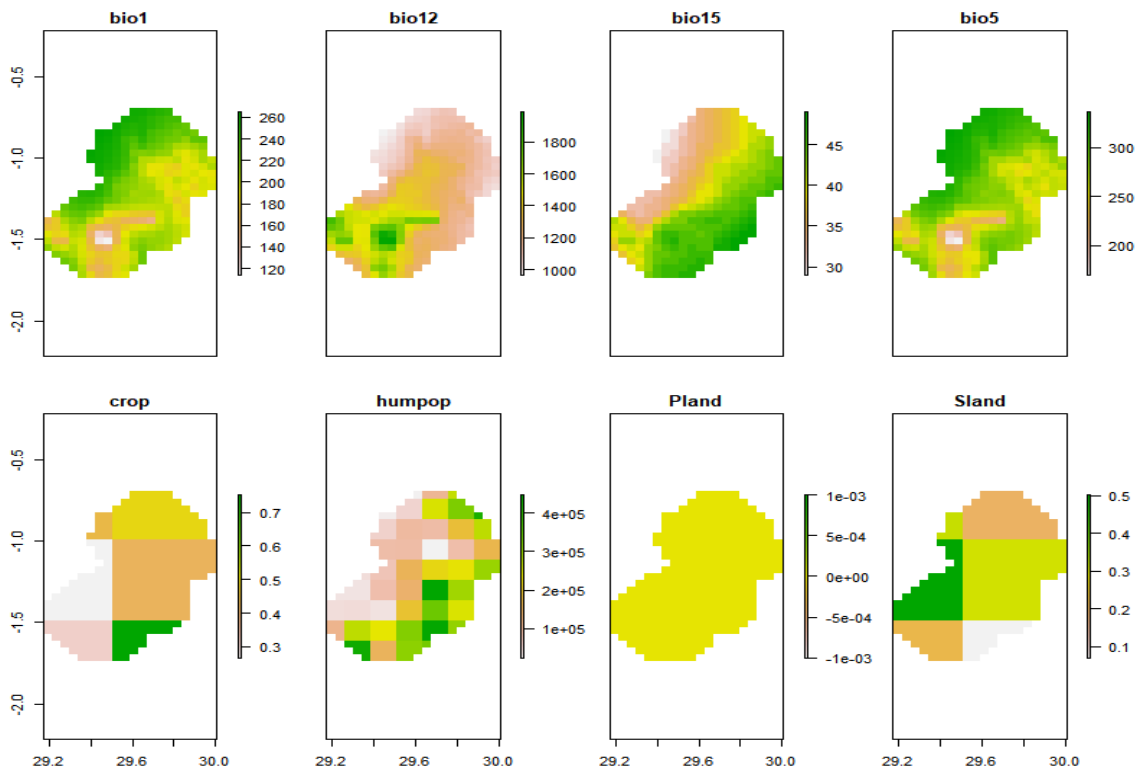
**Current**



**Best scenario**

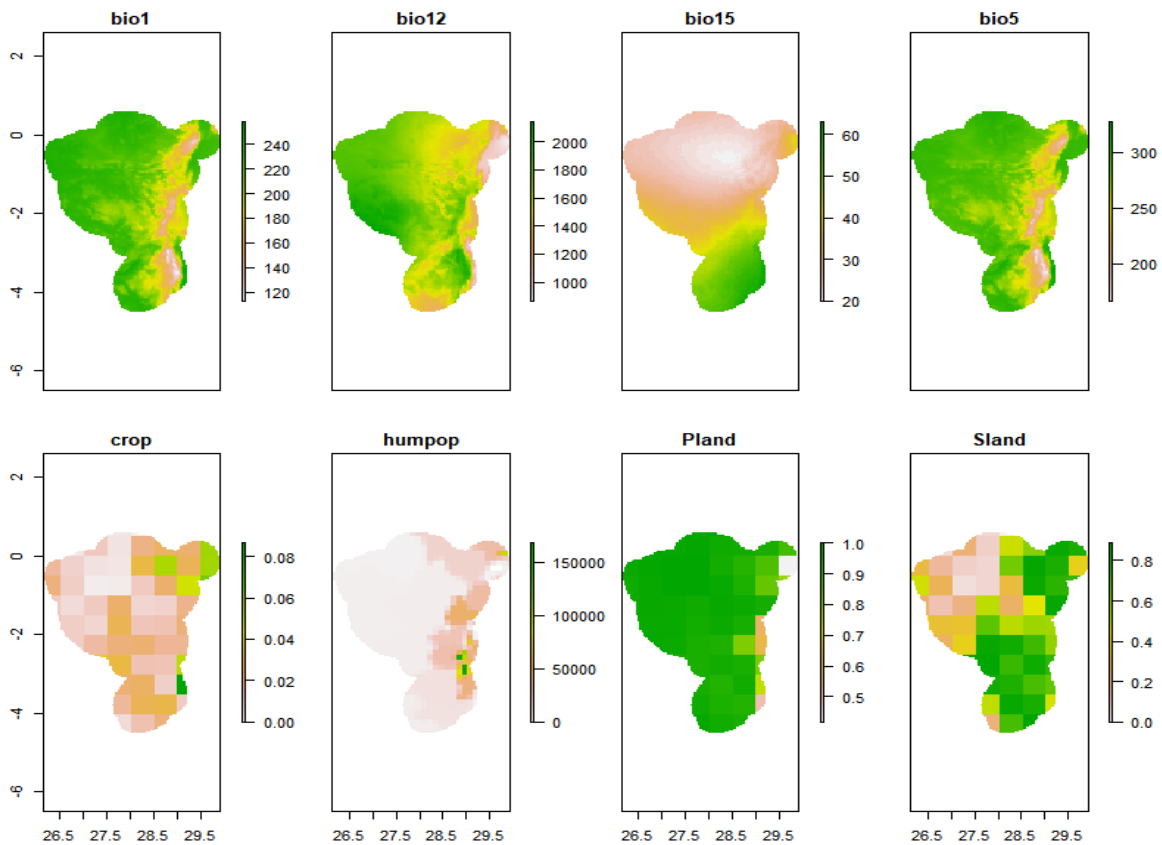


**Worst scenario**

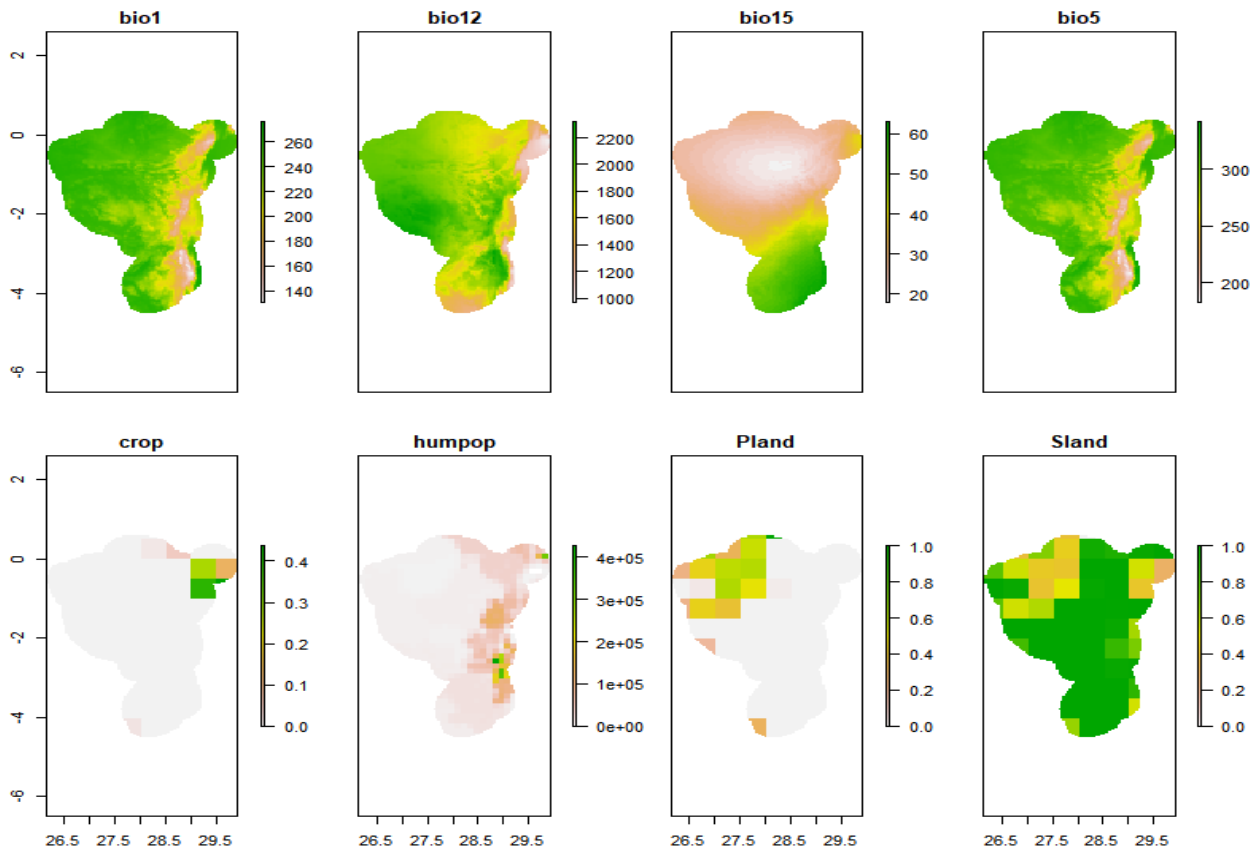


*Gorilla beringei graueri*

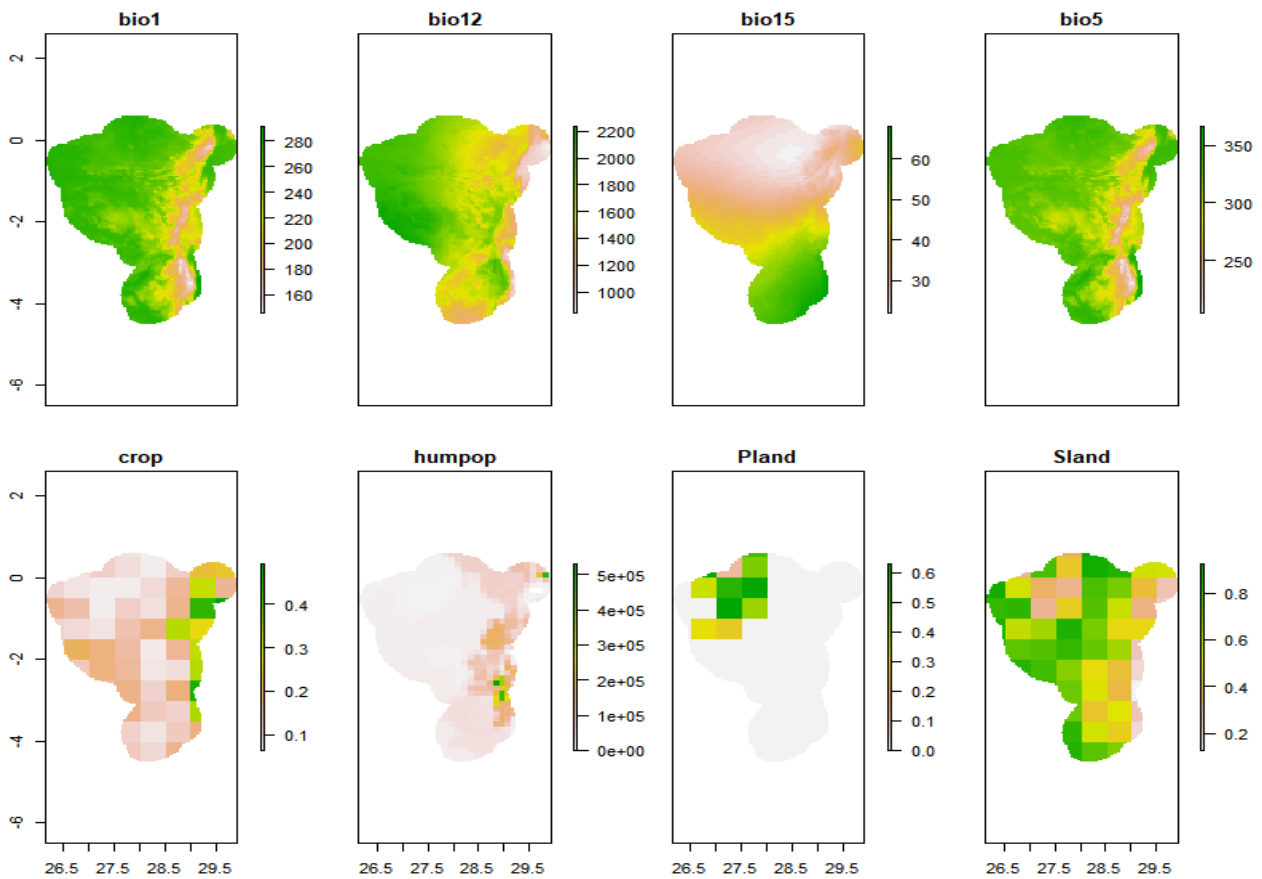
**Current**



**Best scenario**



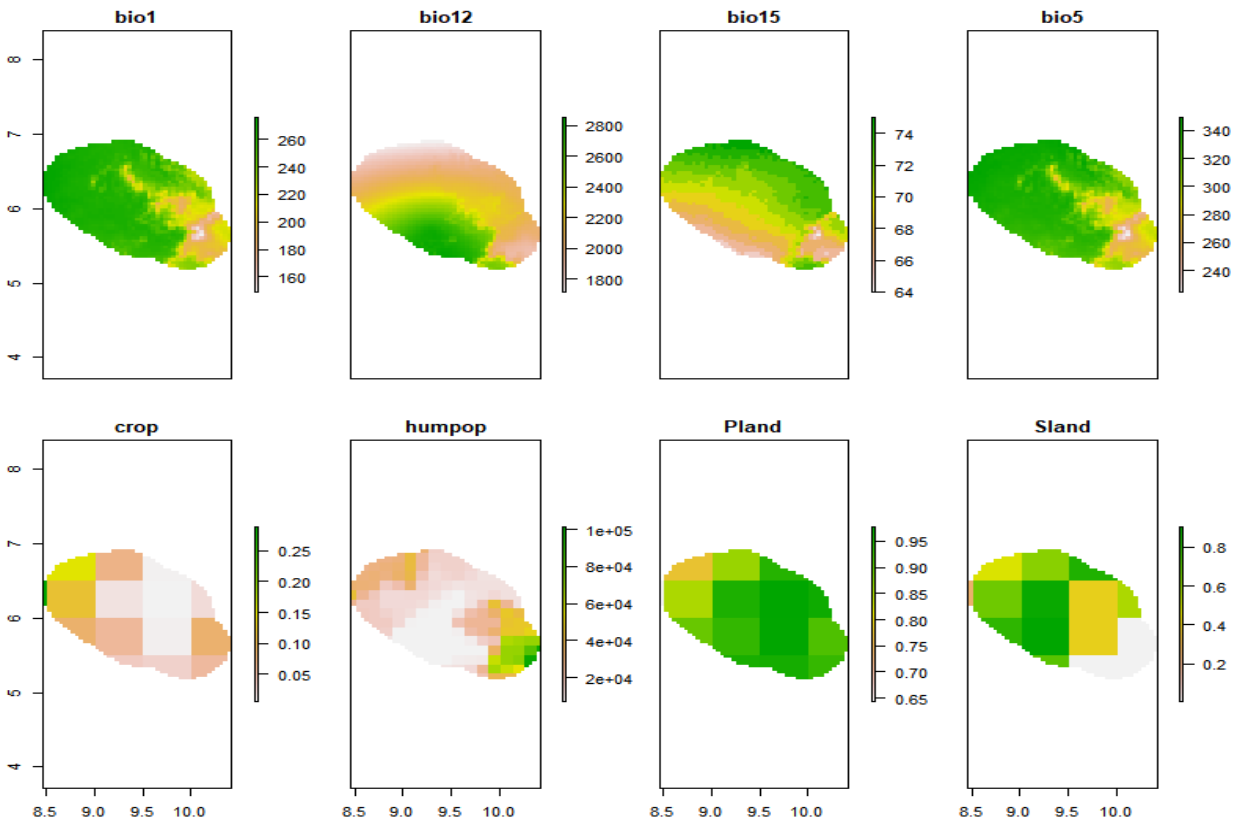
**Worst scenario**



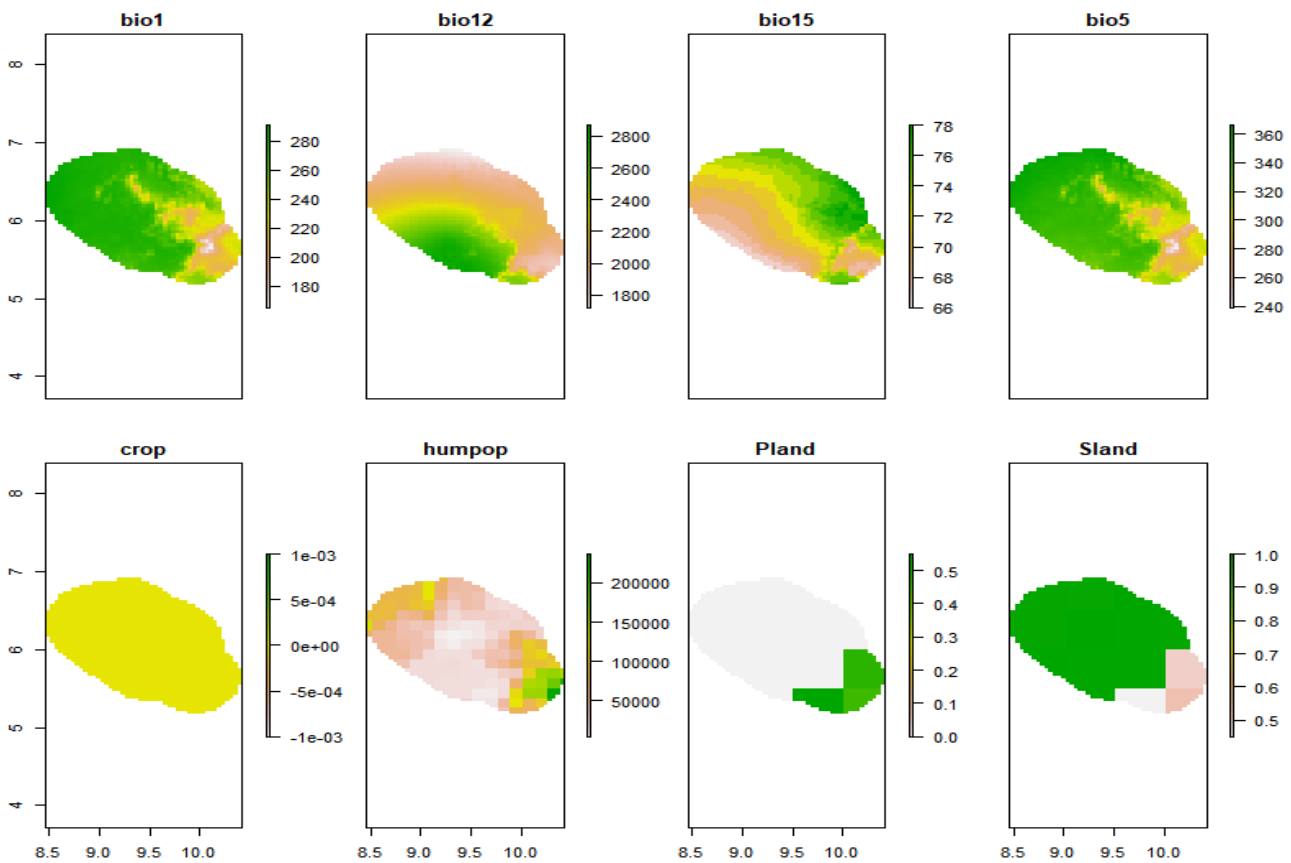


*Gorilla gorilla diehli*

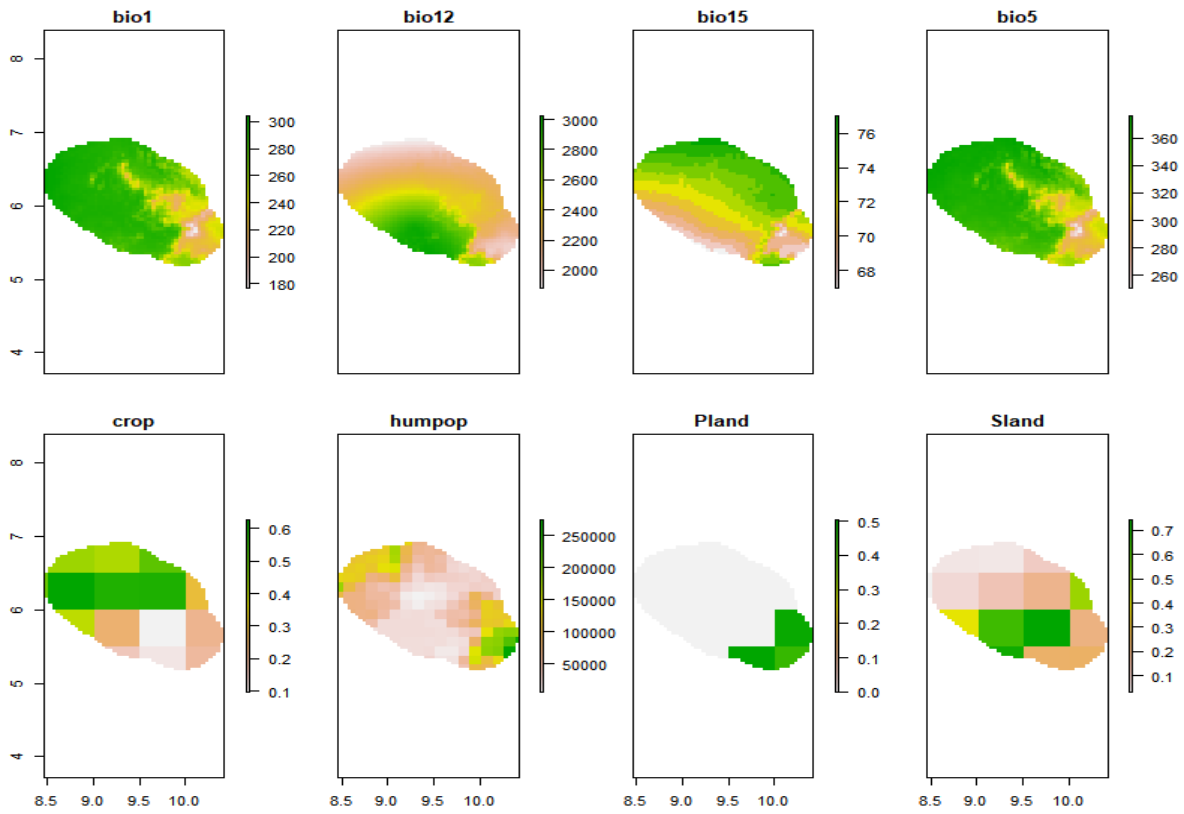
**Current**



**Best scenario**

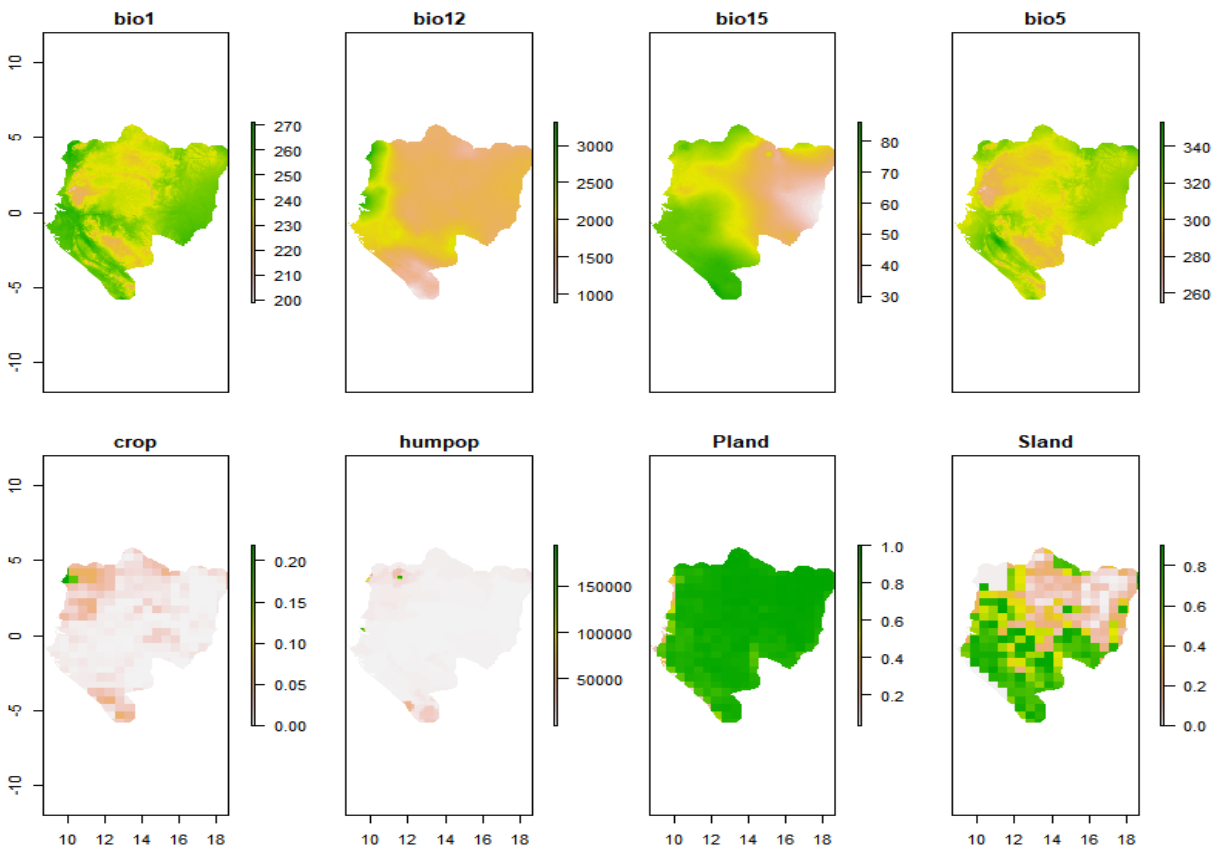


**Worst scenario**

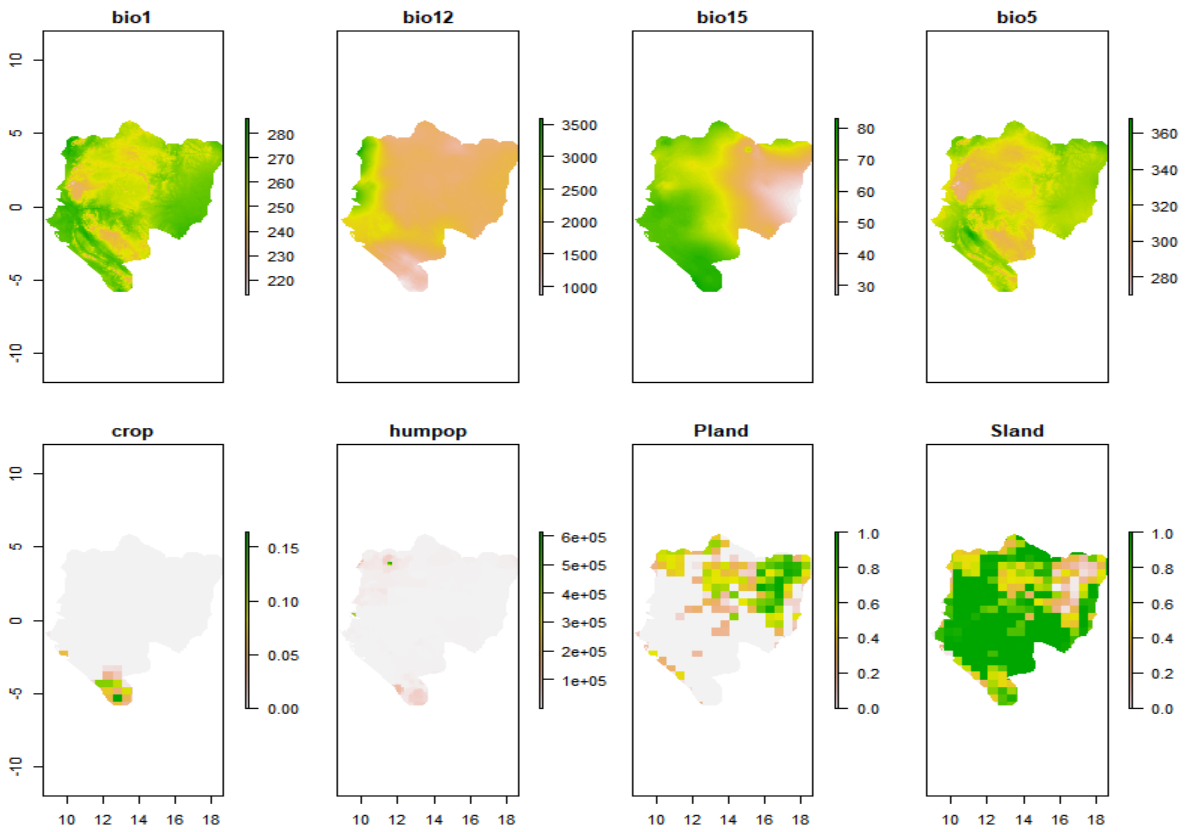


*Gorilla gorilla gorilla*

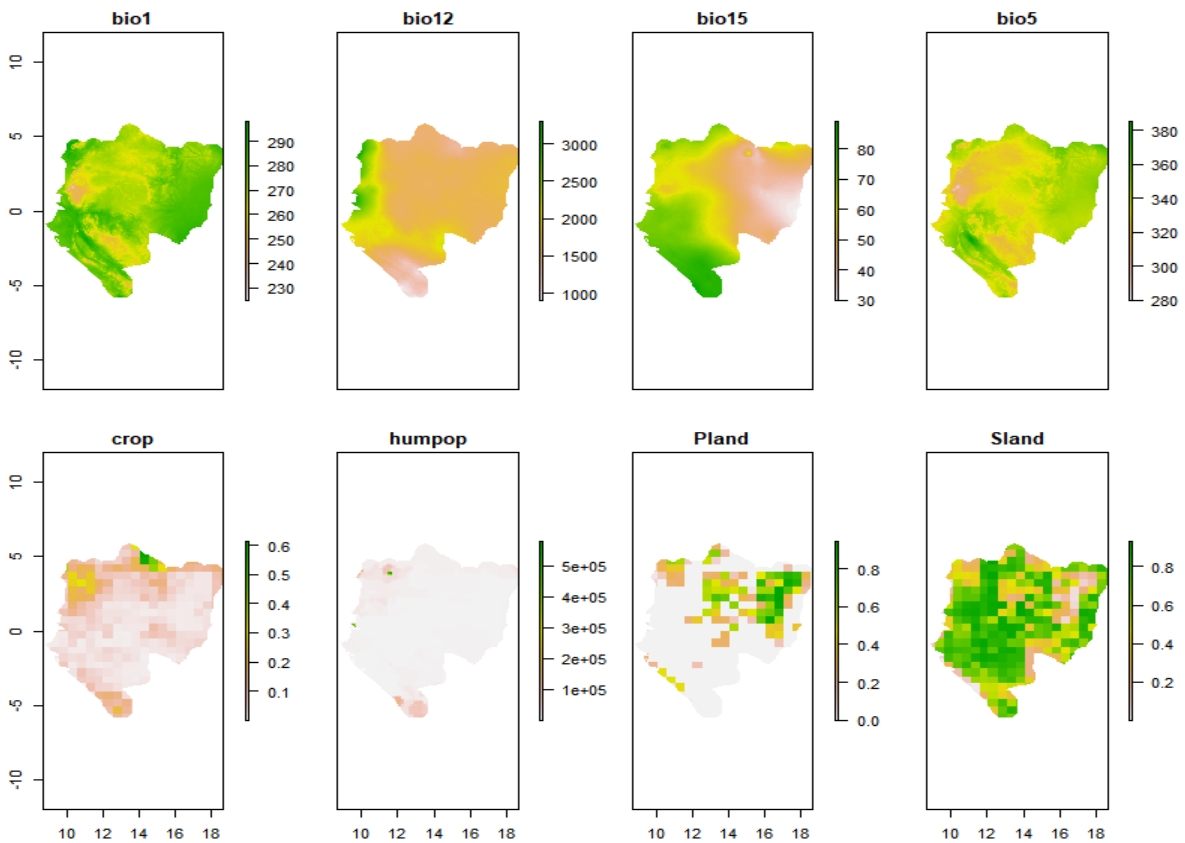
**Current**



**Best scenario**

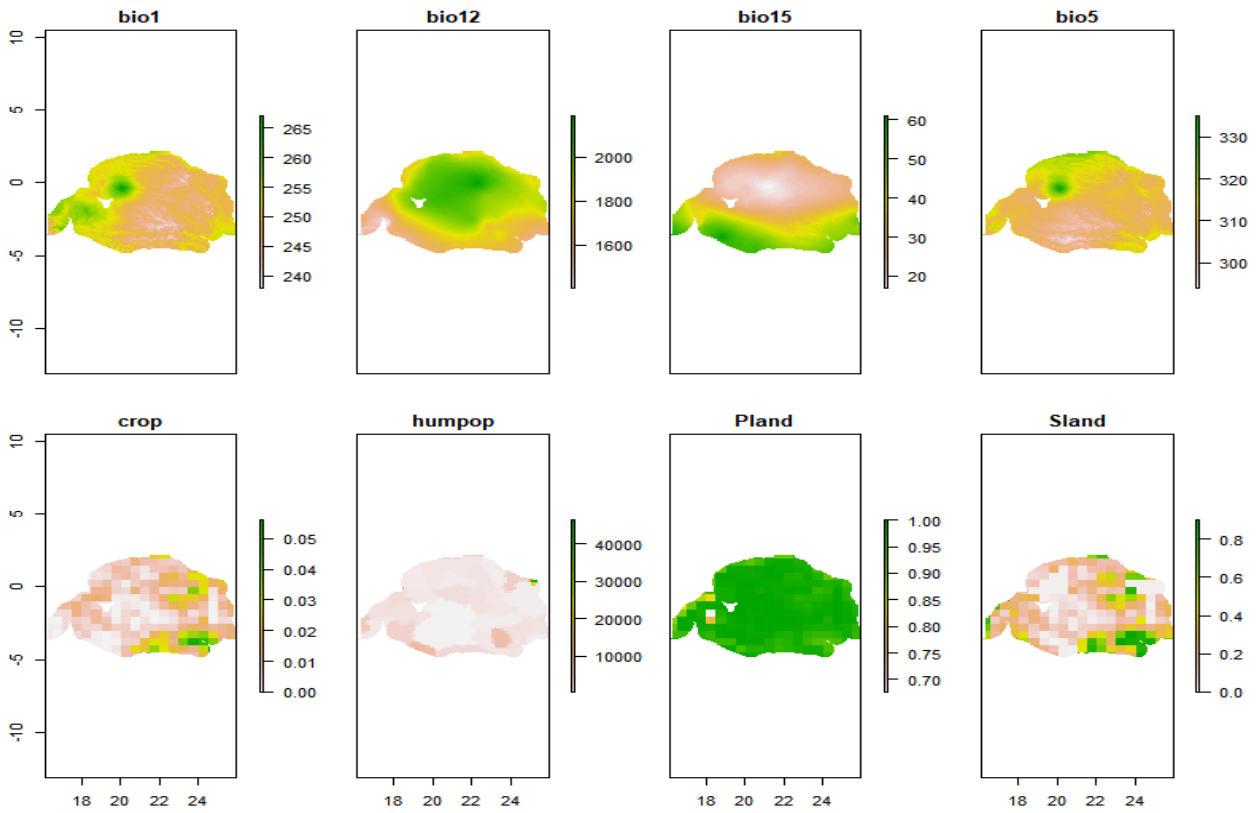


**Worst scenario**

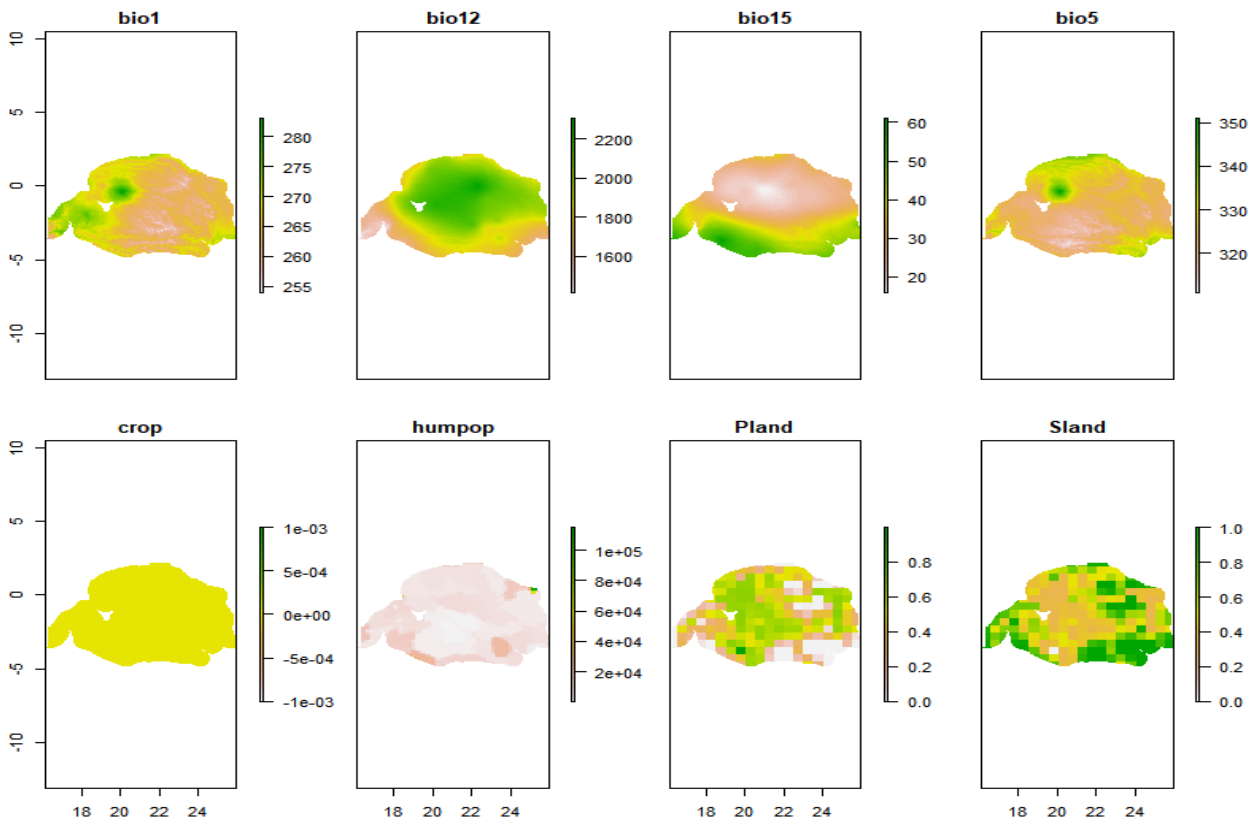


*Pan paniscus*

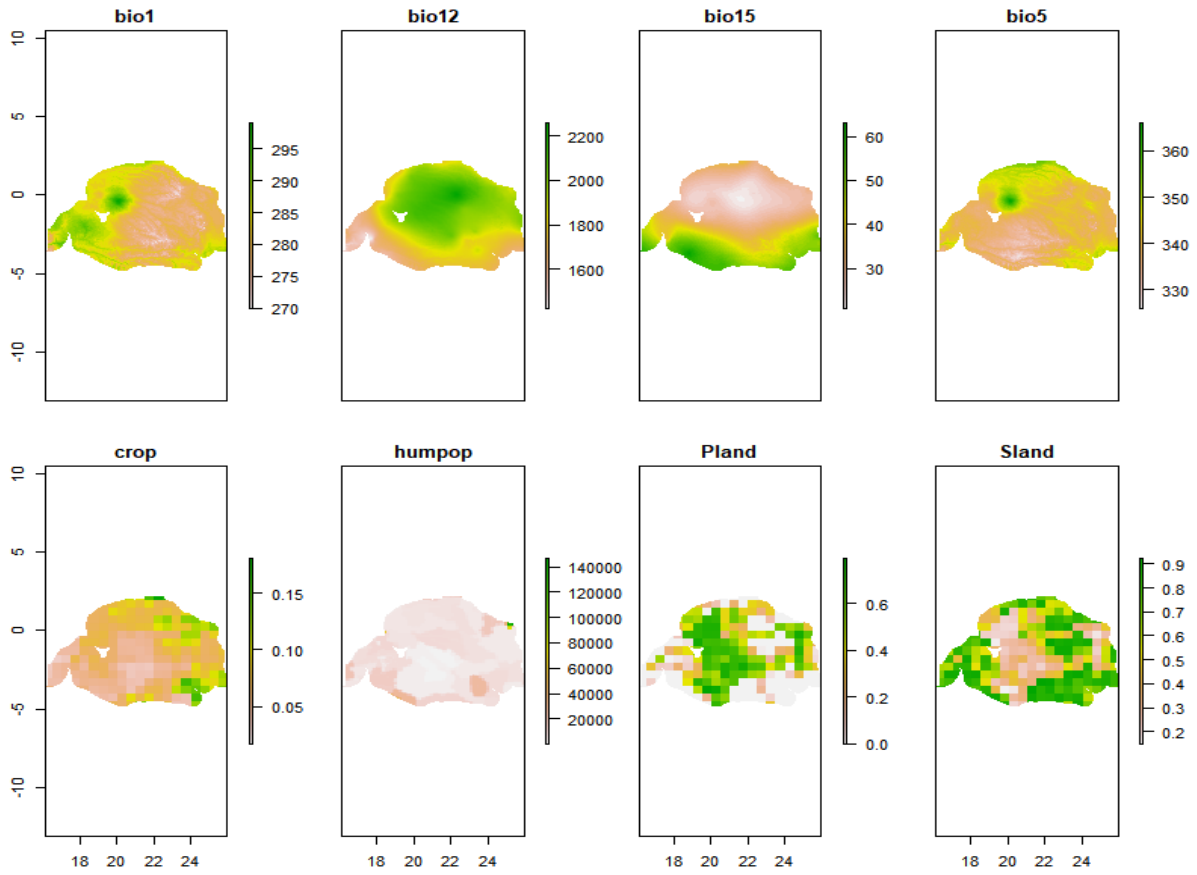
**Current**



**Best scenario**

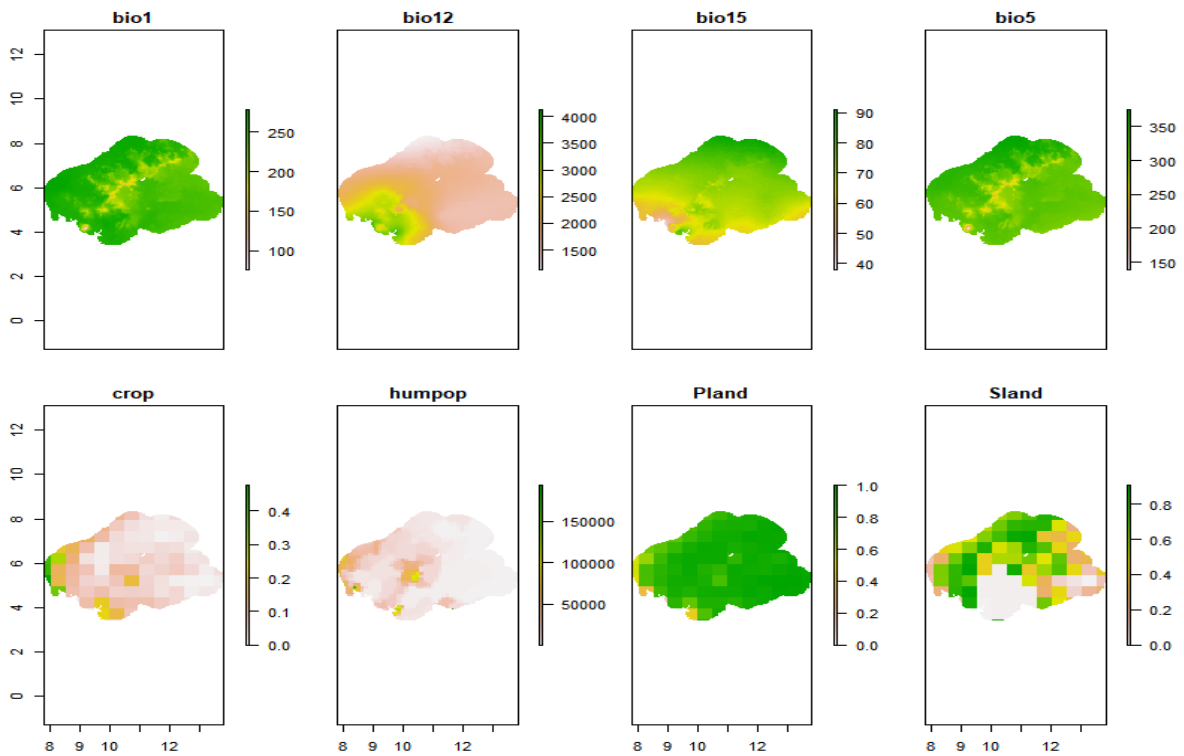


**Worst scenario**

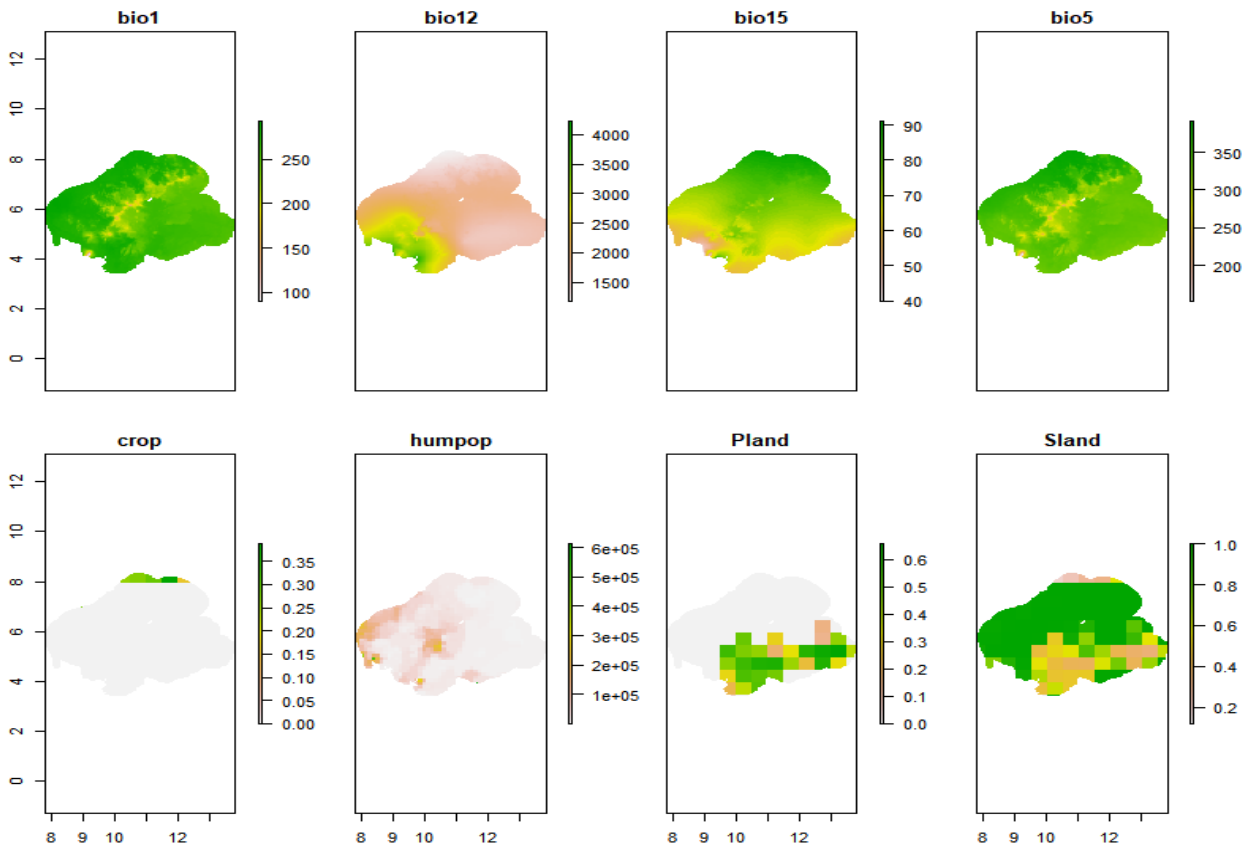


*Pan troglodytes ellioti*

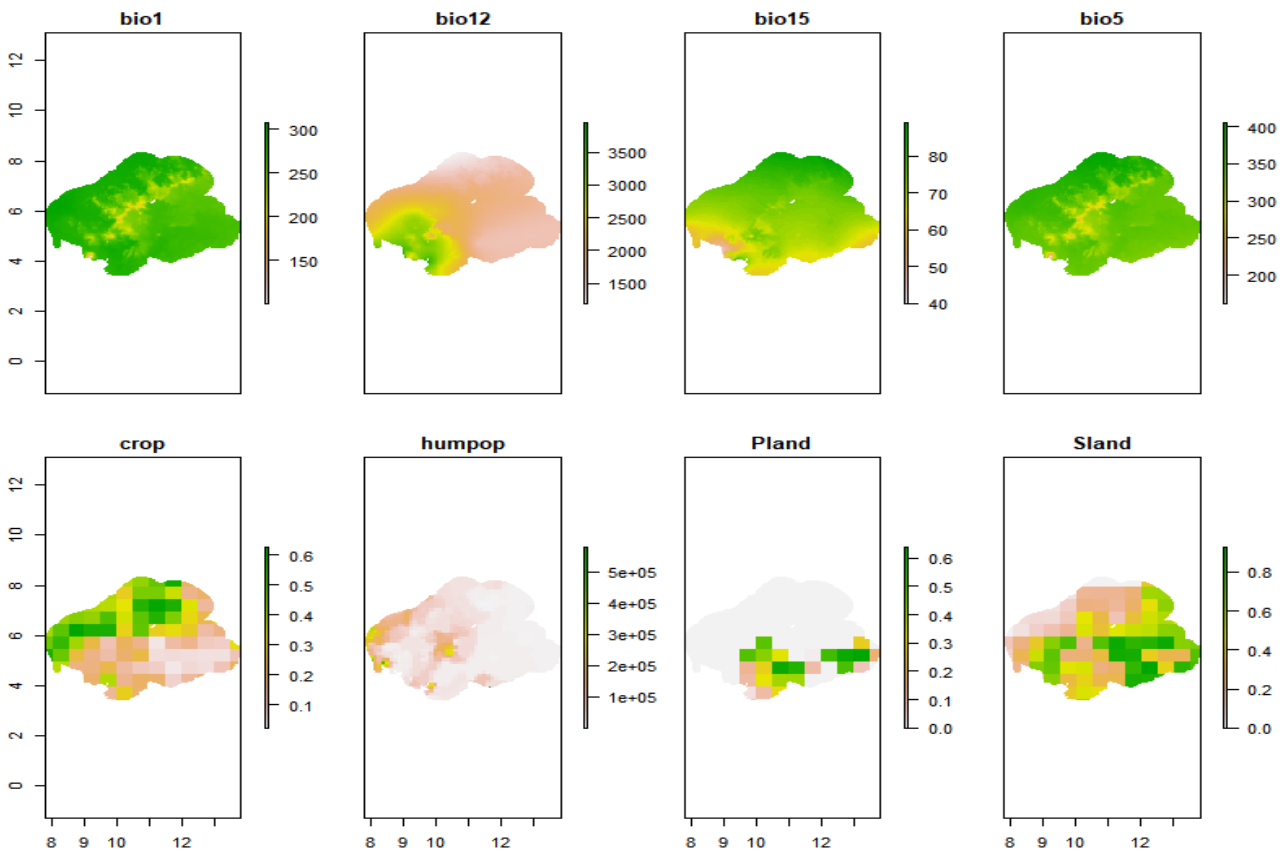
**Current**



**Best scenario**

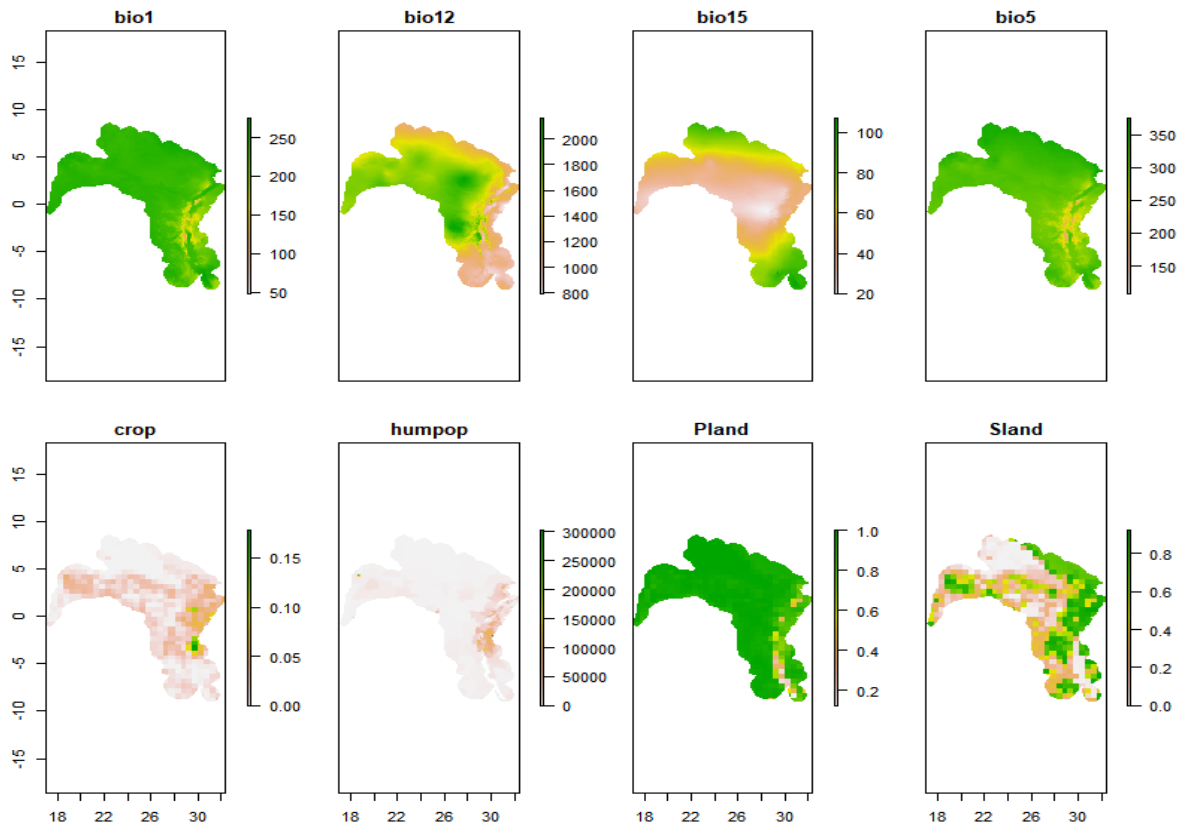


**Worst scenario**

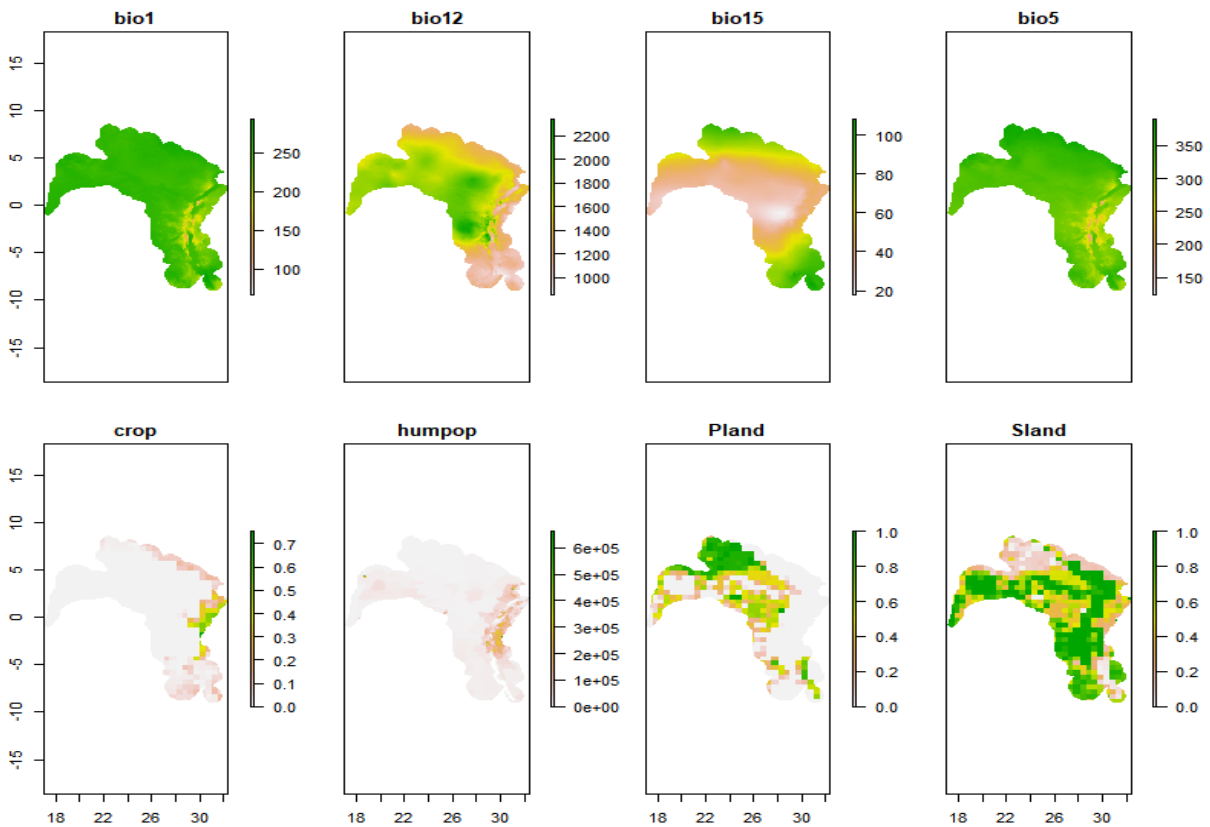


*Pan troglodytes schweinfurthii*

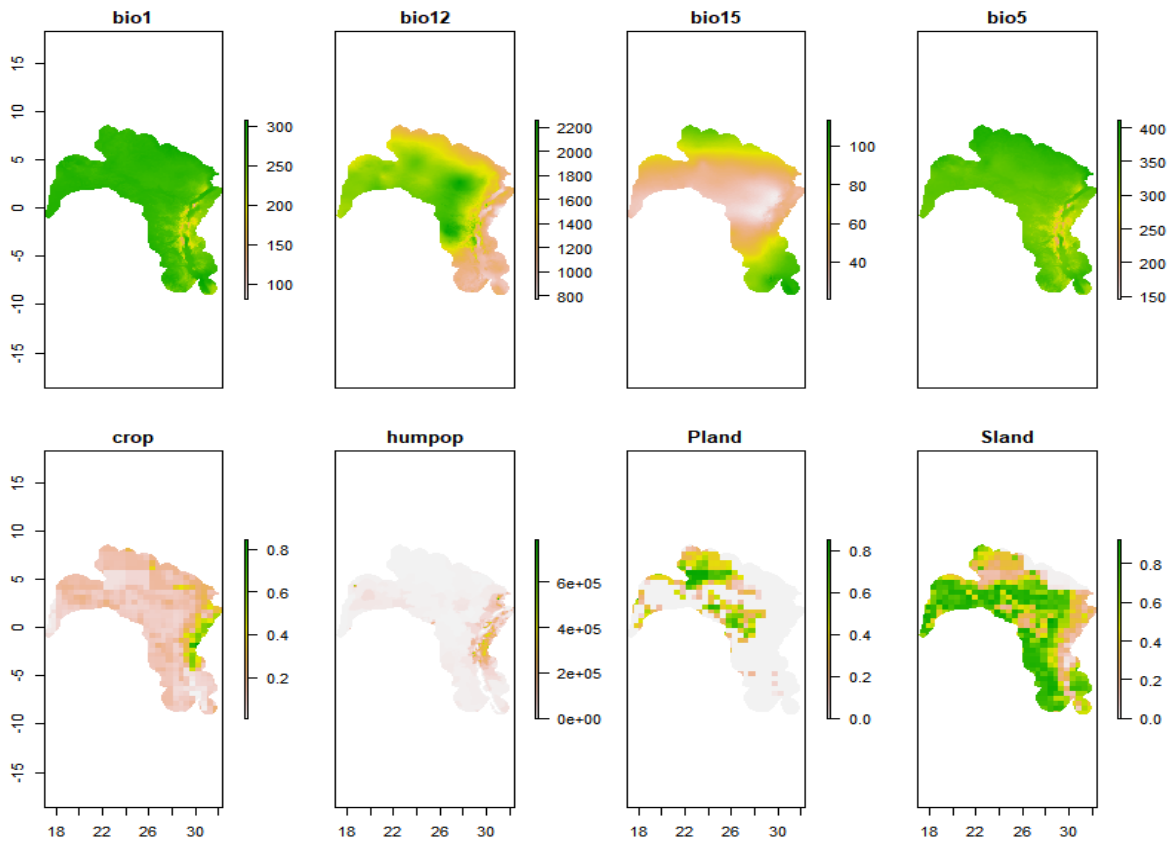
**Current**



**Best scenario**

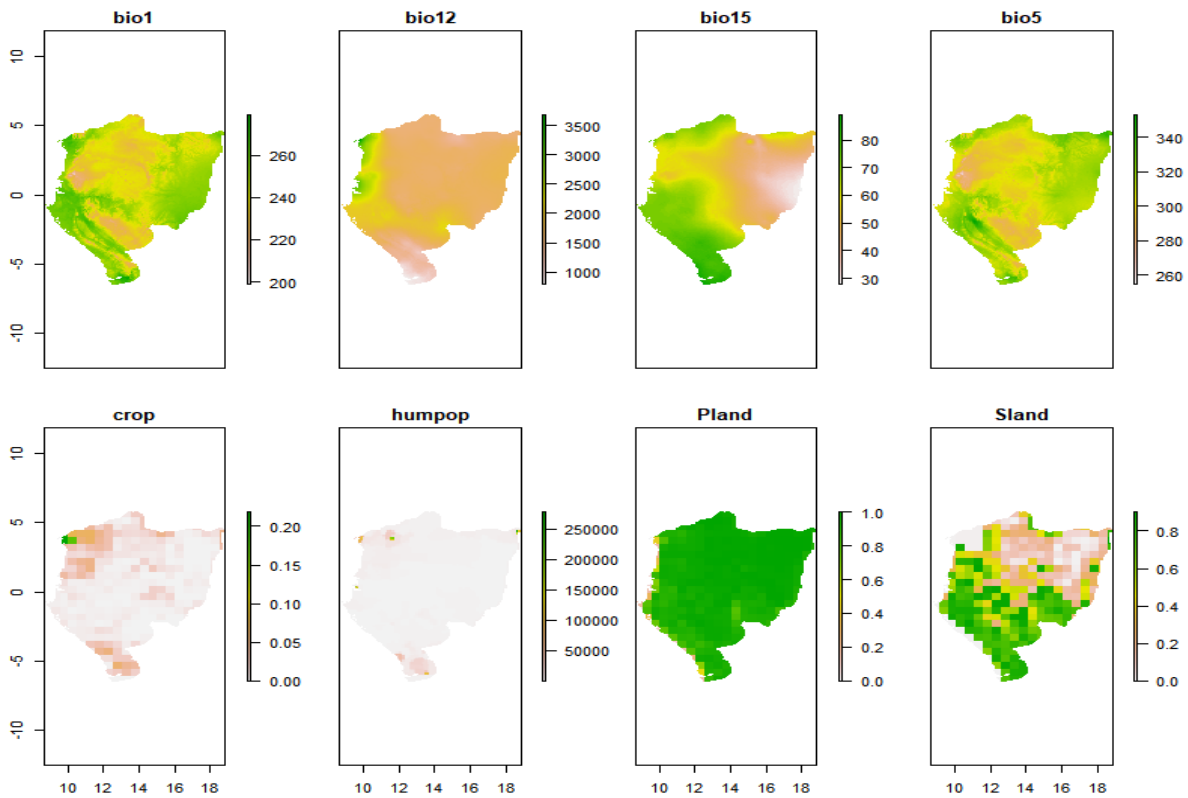


**Worst scenario**



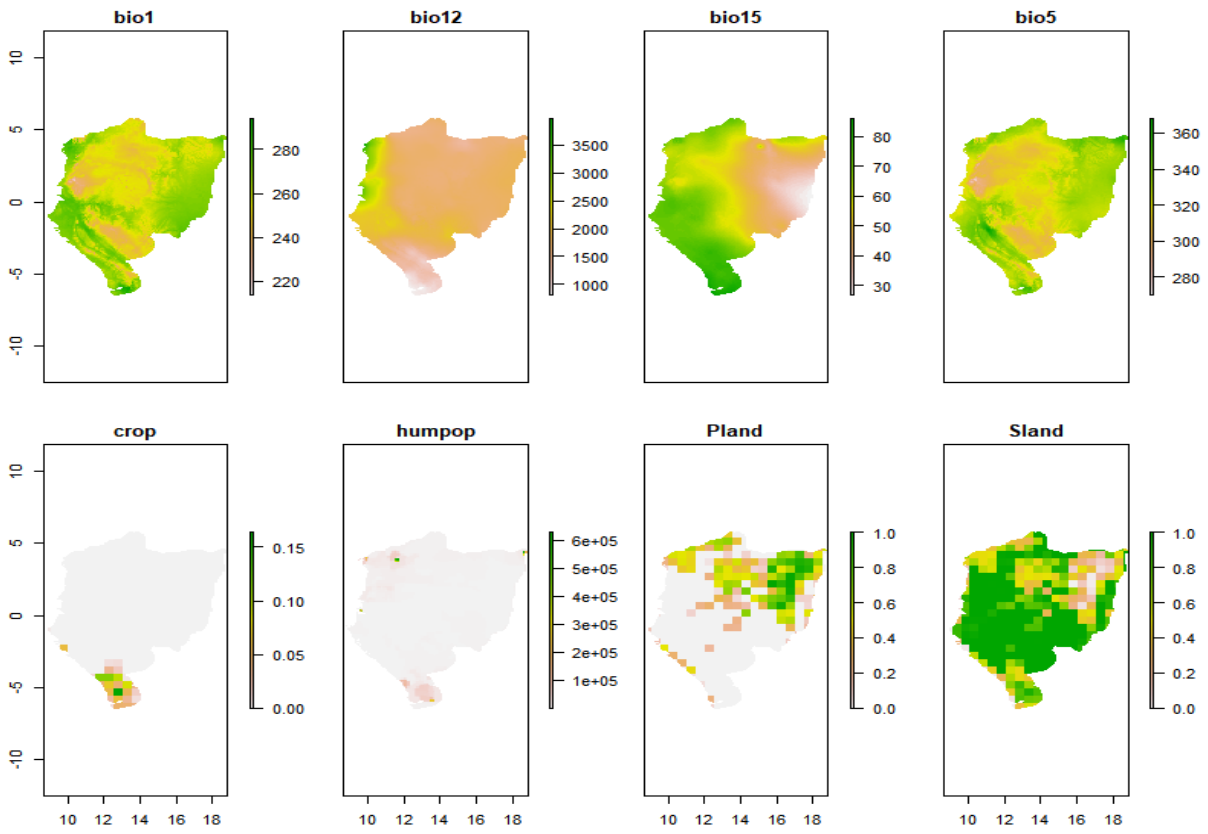
*Pan troglodytes troglodytes*

**Current**

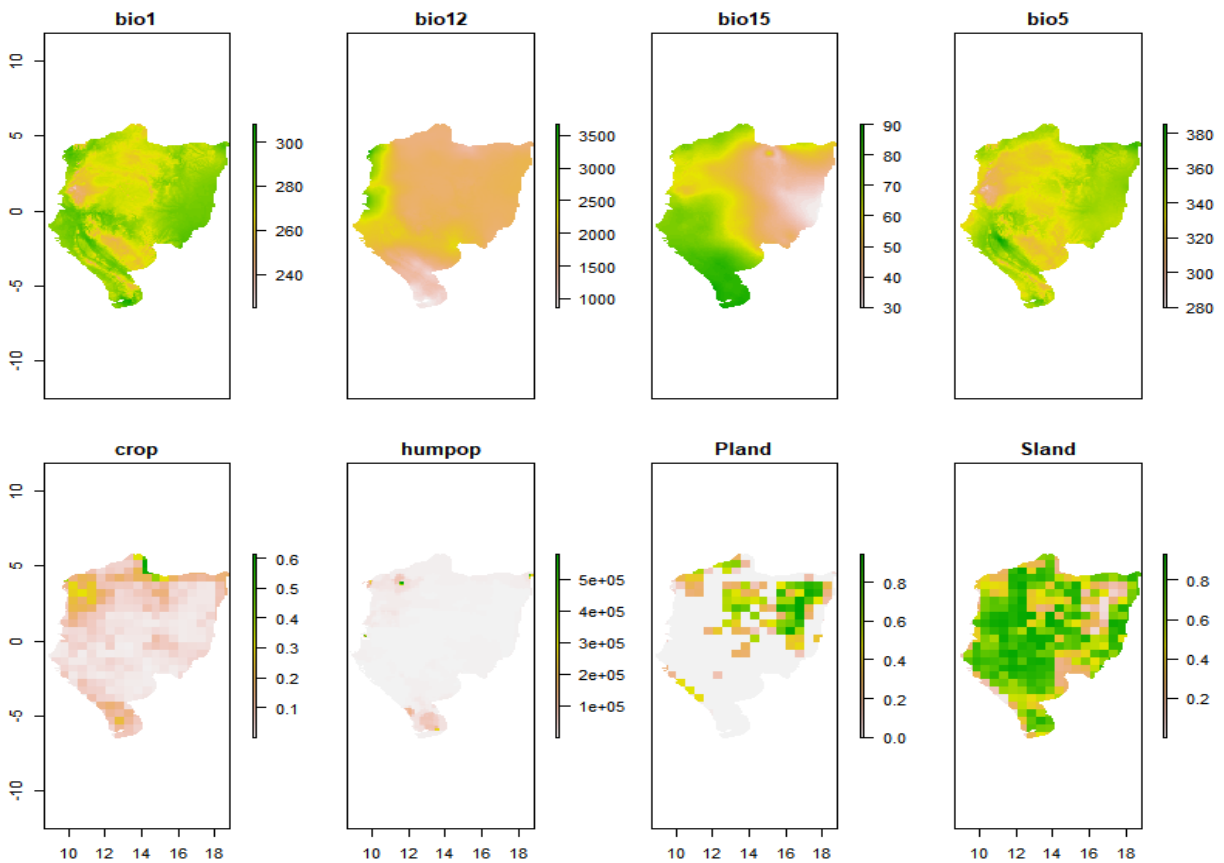




**Best scenario**

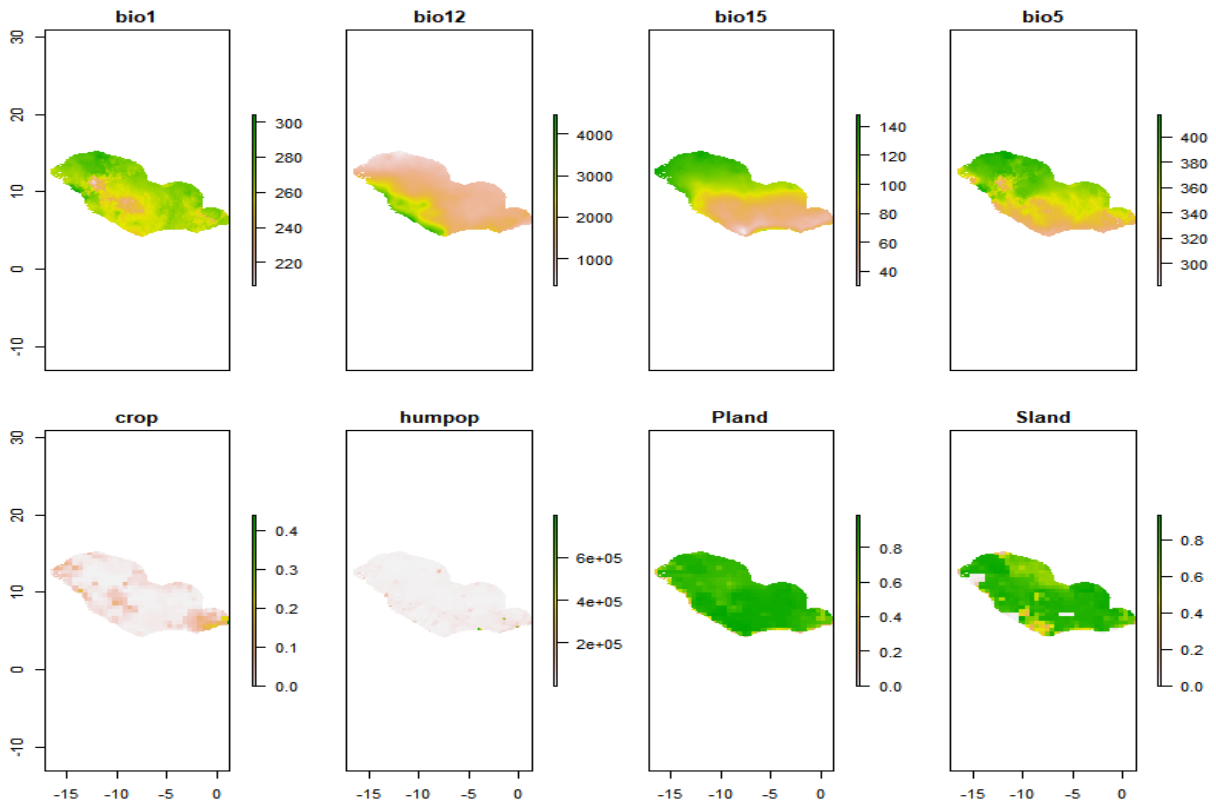


**Worst scenario**

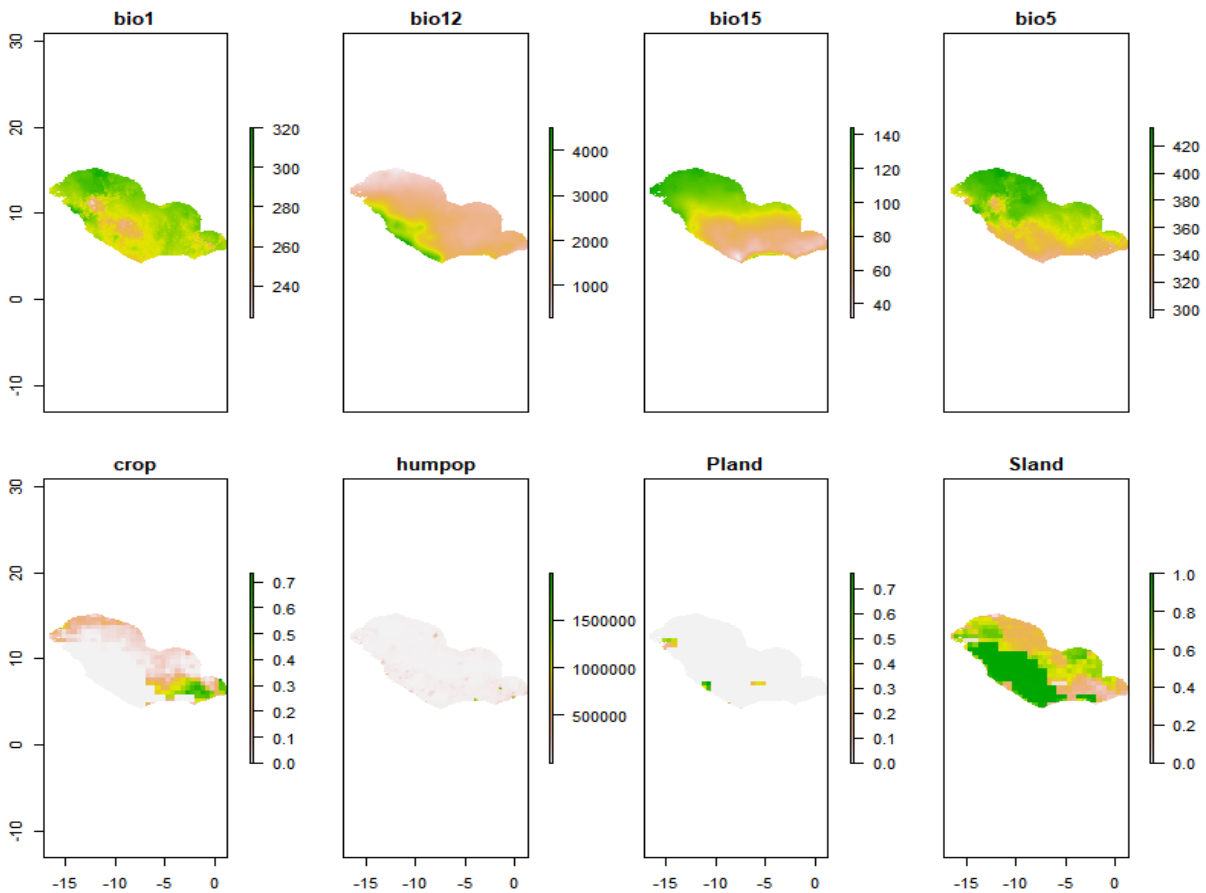


*Pan troglodytes verus*

**Current**



**Best scenario**



**Worst scenario**

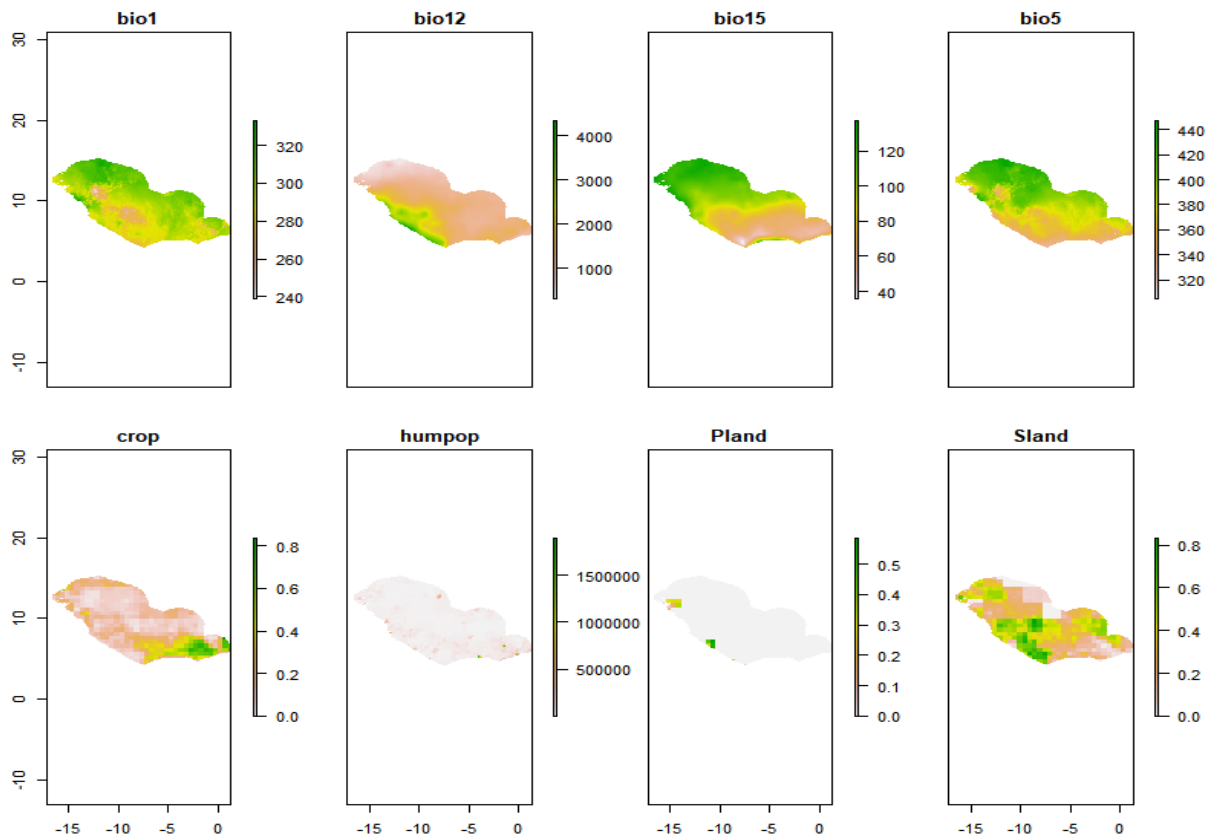


Figure S1.4. Variable predictors under current and future conditions used for predicting African ape distribution. Note that temperature variables are plotted in their original scale (i.e. °C \* 10), as well as all land use variables (% /100) and human population density (km<sup>2</sup> \*1,000).